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## 24MSPS 16-bit CCD Digitiser

### DESCRIPTION

The WM8213 is a 16-bit analogue front end/digitiser IC which processes and digitises the analogue output signals from CCD sensors or Contact Image Sensors (CIS) at pixel sample rates of up to 24MSPS.

The device includes three analogue signal processing channels each of which contains Reset Level Clamping, Correlated Double Sampling and Programmable Gain and Offset adjust functions. Three multiplexers allow single channel processing. The output from each of these channels is time multiplexed into a single high-speed 16-bit Analogue to Digital Converter. The digital output data is available in 8-bit wide multiplexed format and there is also an optional single byte output mode, or 4-bit multiplexed LEGACY mode.

An internal 4-bit DAC is supplied for internal reference level generation. This may be used during CDS to reference CIS signals or during Reset Level Clamping to clamp CCD signals. An external reference level may also be supplied. ADC references are generated internally, ensuring optimum performance from the device.

Using an analogue supply voltage of 3.3V and a digital interface supply of 3.3V, the WM8213 typically only consumes 350mW.

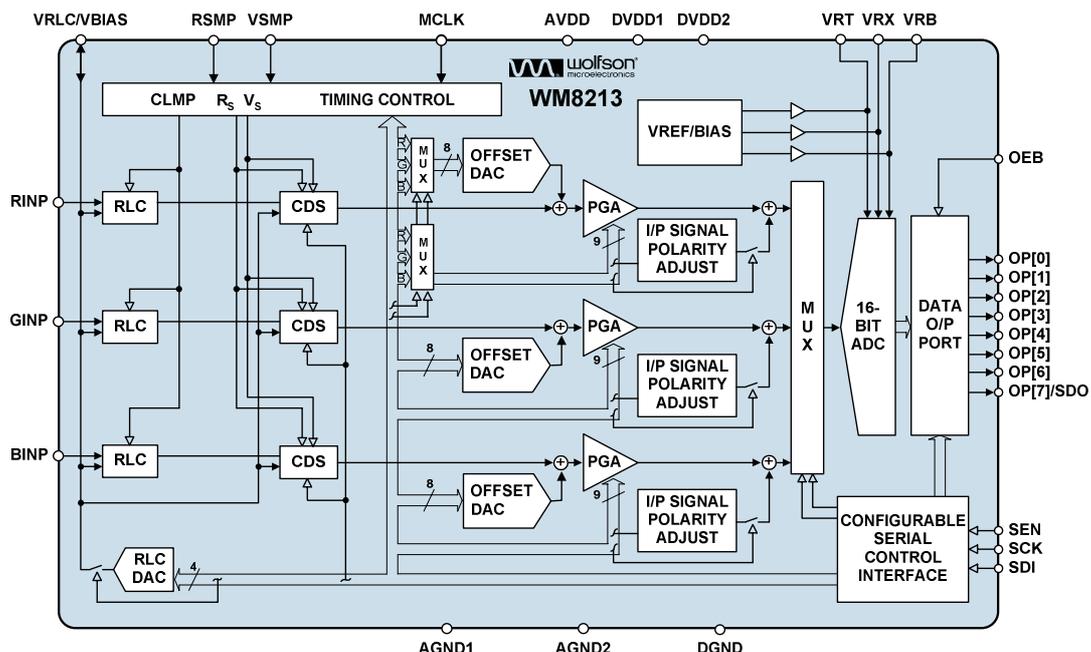
### FEATURES

- 16-bit ADC
- 24MSPS conversion rate
- Low power – 350mW typical
- 3.3V single supply operation
- Single, 2 or 3 channel operation
- Correlated double sampling
- Programmable gain (9-bit resolution)
- Programmable offset adjust (8-bit resolution)
- Flexible clamp control with programmable clamp voltage
- Flexible timing, can be made compatible with WM819X and WM815X parts.
- 8-bit wide multiplexed data output format
- 8-bit only output mode
- 4-bit LEGACY multiplexed nibble mode
- Internally generated voltage references
- 28-lead SSOP package, pin compatible with WM8199
- Serial control interface

### APPLICATIONS

- High speed USB2.0 compatible scanners
- Multi-function peripherals
- High-performance CCD sensor interface
- Digital Copiers

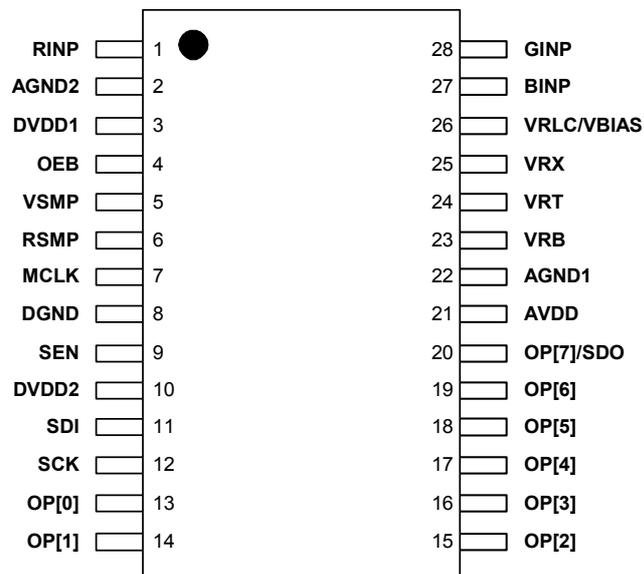
### BLOCK DIAGRAM



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## PIN CONFIGURATION



## ORDERING INFORMATION

DEVICE	TEMP. RANGE	PACKAGE	MOISTURE SENSITIVITY LEVEL	PEAK SOLDERING TEMPERATURE
WM8213SCDS/V	0 to 70°C	28-lead SSOP (Pb-free)	MSL3	260°C
WM8213SCDS/RV	0 to 70°C	28-lead SSOP (Pb-free, tape and reel)	MSL3	260°C

**Note:**

Reel quantity = 2,000

## PIN DESCRIPTION

PIN	NAME	TYPE	DESCRIPTION
1	RINP	Analogue input	Red channel input video.
2	AGND2	Supply	Analogue ground reference.
3	DVDD1	Supply	Digital supply for logic and clock generator. This must be operated at the same potential as AVDD.
4	OEB	Digital input	Output Hi-Z control, all digital outputs disabled when register bit OEB = 1 or register bit OPD = 1.
5	VSMP	Digital input	Video sample timing pulse.
6	RSMP	Digital input	Reset sample timing pulse (also used for RLC control).
7	MCLK	Digital input	Master (ADC) clock. This determines the ADC conversion rate.
8	DGND	Supply	Digital ground reference.
9	SEN	Digital input	Enables the serial interface when high.
10	DVDD2	Supply	Digital supply, all digital I/O pins.
11	SDI	Digital input	Serial data input.
12	SCK	Digital input	Serial clock.
			Digital multiplexed output data bus. ADC output data (d15:d0) is available in multiplexed format as shown. See 'Output Formats' description in Device Description section for details of other output modes.
			<b>A</b>
			<b>B</b>
13	OP[0]	Digital output	d8
14	OP[1]	Digital output	d9
15	OP[2]	Digital output	d10
16	OP[3]	Digital output	d11
17	OP[4]	Digital output	d12
18	OP[5]	Digital output	d13
19	OP[6]	Digital output	d14
20	OP[7]/SDO	Digital output	d15
			Alternatively, pin OP[7]/SDO may be used to output register read-back data when register bit OEB = 0, OPD = 0 and SEN has been pulsed high. See Serial Interface description in Device Description section for further details.
21	AVDD	Supply	Analogue supply. This must be operated at the same potential as DVDD1.
22	AGND1	Supply	Analogue ground reference.
23	VRB	Analogue output	Lower reference voltage. This pin must be connected to AGND via a decoupling capacitor.
24	VRT	Analogue output	Upper reference voltage. This pin must be connected to AGND via a decoupling capacitor.
25	VRX	Analogue output	Input return bias voltage. This pin must be connected to AGND via a decoupling capacitor.
26	VRLC/VBIAS	Analogue I/O	Selectable analogue output voltage for RLC or single-ended bias reference. This pin would typically be connected to AGND via a decoupling capacitor. VRLC can be externally driven if programmed Hi-Z.
27	BINP	Analogue input	Blue channel input video.
28	GINP	Analogue input	Green channel input video.

## ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings are stress ratings only. Permanent damage to the device may be caused by continuously operating at or beyond these limits. Device functional operating limits and guaranteed performance specifications are given under Electrical Characteristics at the test conditions specified.



ESD Sensitive Device. This device is manufactured on a CMOS process. It is therefore generically susceptible to damage from excessive static voltages. Proper ESD precautions must be taken during handling and storage of this device.

Wolfson tests its package types according to IPC/JEDEC J-STD-020B for Moisture Sensitivity to determine acceptable storage conditions prior to surface mount assembly. These levels are:

MSL1 = unlimited floor life at <30°C / 85% Relative Humidity. Not normally stored in moisture barrier bag.

MSL2 = out of bag storage for 1 year at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.

MSL3 = out of bag storage for 168 hours at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.

The Moisture Sensitivity Level for each package type is specified in Ordering Information.

CONDITION	MIN	MAX
Analogue supply voltage: AVDD	GND - 0.3V	GND + 5V
Digital supply voltages: DVDD1 – 2	GND - 0.3V	GND + 5V
Digital ground: DGND	GND - 0.3V	GND + 0.3V
Analogue grounds: AGND1 – 2	GND - 0.3V	GND + 0.3V
Digital inputs, digital outputs and digital I/O pins	GND - 0.3V	DVDD2 + 0.3V
Analogue inputs (RINP, GINP, BINP)	GND - 0.3V	AVDD + 0.3V
Other pins	GND - 0.3V	AVDD + 0.3V
Operating temperature range: T <sub>A</sub>	0°C	+70°C
Storage temperature after soldering	-65°C	+150°C

### Notes:

- GND denotes the voltage of any ground pin.
- AGND1, AGND2 and DGND pins are intended to be operated at the same potential. Differential voltages between these pins will degrade performance.

## RECOMMENDED OPERATING CONDITIONS

CONDITION	SYMBOL	MIN	TYP	MAX	UNITS
Operating temperature range	T <sub>A</sub>	0		70	°C
Analogue supply voltage	AVDD	2.97	3.3	3.63	V
Digital core supply voltage	DVDD1	2.97	3.3	3.63	V
Digital I/O supply voltage	DVDD2	2.97	3.3	3.63	V

### Notes:

- DVDD2 should be operated at the same potential as DVDD1 ± 0.3V.

## THERMAL PERFORMANCE

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Performance</b>						
Thermal resistance – junction to case	R <sub>θJC</sub>	T <sub>ambient</sub> = 25°C		23.9		°C/W
Thermal resistance – junction to ambient	R <sub>θJA</sub>			67.1		°C/W

### Notes:

- Figures given are for package mounted on 4-layer FR4 according to JESD51-5 and JESD51-7.

## ELECTRICAL CHARACTERISTICS

## Test Conditions

AVDD = DVDD1 = DVDD2 = 3.3V, AGND = DGND = 0V, T<sub>A</sub> = 25°C, MCLK = 24MHz unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Overall System Specification (including 16-bit ADC, PGA, Offset and CDS functions)</b>						
Conversion rate				24		MSPS
Full-scale input voltage range (see Note 1)		LOWREFS=0, Max Gain		0.25		Vp-p
		LOWREFS=0, Min Gain		3.03		Vp-p
		LOWREFS=1, Max Gain		0.15		Vp-p
		LOWREFS=1, Min Gain		1.82		Vp-p
Input signal limits (see Note 2)	V <sub>IN</sub>		AGND-0.3		AVDD+0.3	V
Input Capacitance (R <sub>INP</sub> , G <sub>INP</sub> , B <sub>INP</sub> )				10		pF
Input Impedance (R <sub>INP</sub> , G <sub>INP</sub> , B <sub>INP</sub> )				50		Ω
Full-scale transition error		Gain = 0dB; PGA[8:0] = 18(hex)		20		mV
Zero-scale transition error		Gain = 0dB; PGA[8:0] = 18(hex)		20		mV
Differential non-linearity	DNL			1		LSB
Integral non-linearity	INL			25		LSB
Channel to channel gain matching				1		%
Total output noise		Min Gain		12.4		LSB rms
		Max Gain		105		LSB rms

<b>References</b>						
Upper reference voltage	VRT	LOWREFS=0 LOWREFS=1	1.95	2.05 1.85	2.25	V
Lower reference voltage	VRB	LOWREFS=0 LOWREFS=1	0.95	1.05 1.25	1.25	V
Input return bias voltage	VRX			1.25		V
Diff. reference voltage (VRT-VRB)	V <sub>RTB</sub>	LOWREFS=0	0.90	1.0	1.10	V
		LOWREFS=1		0.6		
Output resistance VRT, VRB, VRX				1		Ω

## Notes:

- Full-scale input voltage** denotes the peak input signal amplitude that can be gained to match the ADC full-scale input range.
- Input signal limits** are the limits within which the full-scale input voltage signal must lie.

<b>Test Conditions</b>						
AVDD = DVDD1 = DVDD2 = 3.3V, AGND = DGND = 0V, T <sub>A</sub> = 25°C, MCLK = 24MHz unless otherwise stated.						
PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Reset-Level Clamp (RLC) circuit/ Reference Level DAC</b>						
RLC switching impedance				50		Ω
VRLC short-circuit current				2		mA
VRLC output resistance				2		Ω
VRLC Hi-Z leakage current		VRLC = 0 to AVDD			1	μA
Reference RLCDAC resolution				4		bits
Reference RLCDAC step size	V <sub>RLCSTEP</sub>	AVDD=3.3V RLCDACRNG=0		0.173		V/step
Reference RLCDAC step size	V <sub>RLCSTEP</sub>	RLCDACRNG=1		0.11		V/step
Reference RLCDAC output voltage at code 0(hex)	V <sub>RLCBOT</sub>	AVDD=3.3V, RLCDACRNG=0		0.4		V
Reference RLCDAC output voltage at code 0(hex)	V <sub>RLCBOT</sub>	RLCDACRNG=1		0.4		V
Reference RLCDAC output voltage at code F(hex)	V <sub>RLCTOP</sub>	AVDD=3.3V, RLCDACRNG=0		3.0		V
Reference RLCDAC output voltage at code F(hex)	V <sub>RLCTOP</sub>	RLCDACRNG = 1		2.05		V
RLCDAC	DNL		-0.5		+0.5	LSB
RLCDAC	INL			+/-1		LSB

<b>Offset DAC, Monotonicity Guaranteed</b>						
Resolution				8		bits
Differential non-linearity	DNL			0.1	0.5	LSB
Integral non-linearity	INL			0.25	1	LSB
Step size				2.04		mV/step
Output voltage		Code 00(hex) Code FF(hex)		-260 +260		mV mV

<b>Programmable Gain Amplifier</b>						
Resolution				9		bits
Gain equation				$0.66 + \frac{7.34}{511} * PGA[8:0]$		V/V
Max gain, each channel	G <sub>MAX</sub>			8		V/V
Min gain, each channel	G <sub>MIN</sub>			0.66		V/V
Channel Matching				1	5	%

<b>Analogue to Digital Converter</b>						
Resolution				16		bits
Speed					24	MSPS
Full-scale input range (2*(VRT-VRB))		LOWREFS=0		2		V
		LOWREFS=1		1.2		V

DIGITAL SPECIFICATIONS						
Digital Inputs						
High level input voltage	$V_{IH}$		$0.7 * DVDD2$			V
Low level input voltage	$V_{IL}$				$0.2 * DVDD2$	V
High level input current	$I_{IH}$				1	$\mu A$
Low level input current	$I_{IL}$				1	$\mu A$
Input capacitance	$C_I$			5		pF

Digital Outputs						
High level output voltage	$V_{OH}$	$I_{OH} = 1mA$	$DVDD2 - 0.5$			V
Low level output voltage	$V_{OL}$	$I_{OL} = 1mA$			0.5	V
High impedance output current	$I_{OZ}$				1	$\mu A$

Digital IO Pins						
Applied high level input voltage	$V_{IH}$		$0.7 * DVDD2$			V
Applied low level input voltage	$V_{IL}$				$0.2 * DVDD2$	V
High level output voltage	$V_{OH}$	$I_{OH} = 1mA$	$DVDD2 - 0.5$			V
Low level output voltage	$V_{OL}$	$I_{OL} = 1mA$			0.5	V
Low level input current	$I_{IL}$				1	$\mu A$
High level input current	$I_{IH}$				1	$\mu A$
Input capacitance	$C_I$			5		pF
High impedance output current	$I_{OZ}$				1	$\mu A$

Supply Currents						
Total supply current – active (Analogue and Digital) (Three channel mode)				106		mA
Analogue supply current -active (three channel mode)				93		mA
Digital supply current - active (three channel mode)				13		mA
Supply current – full power down mode				20		$\mu A$

INPUT VIDEO SAMPLING

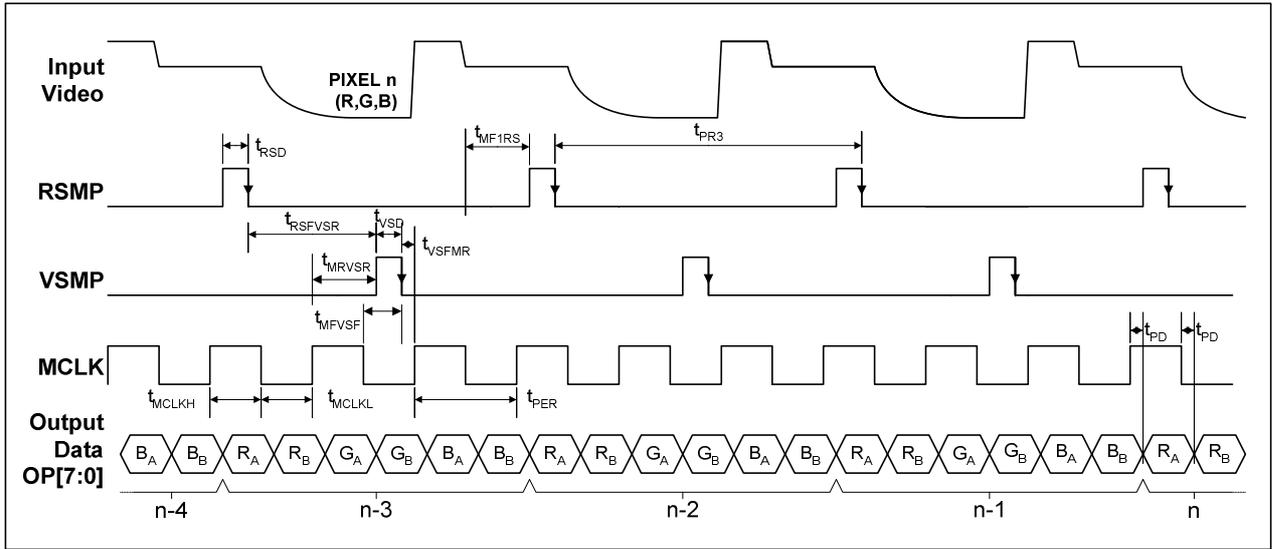


Figure 1 Three-channel CDS Input Video Timing

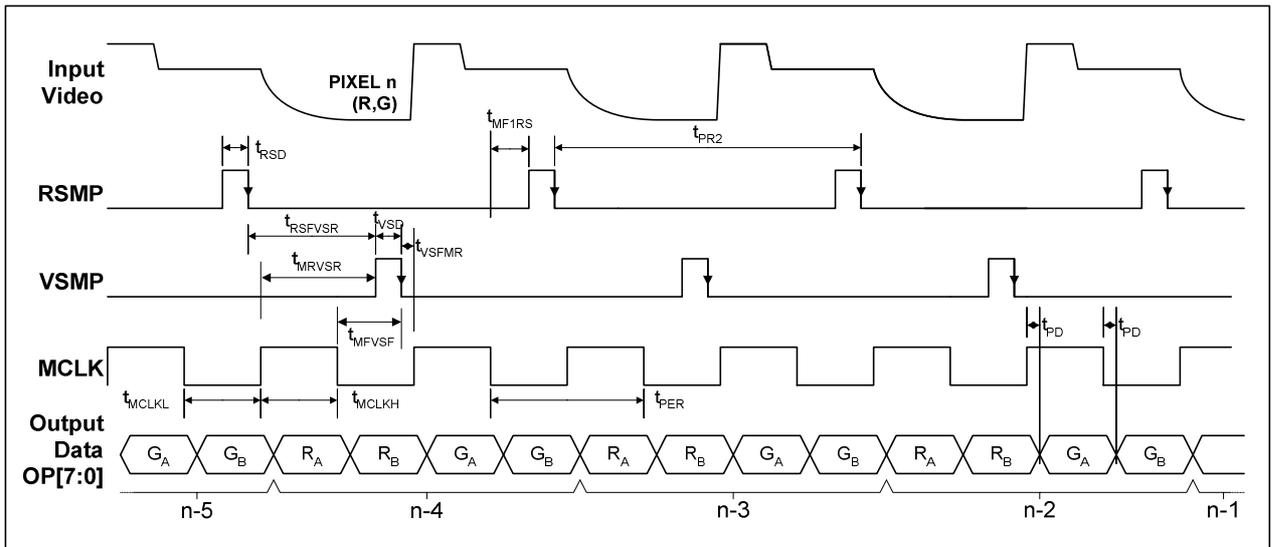


Figure 2 Two-channel CDS Input Video Timing

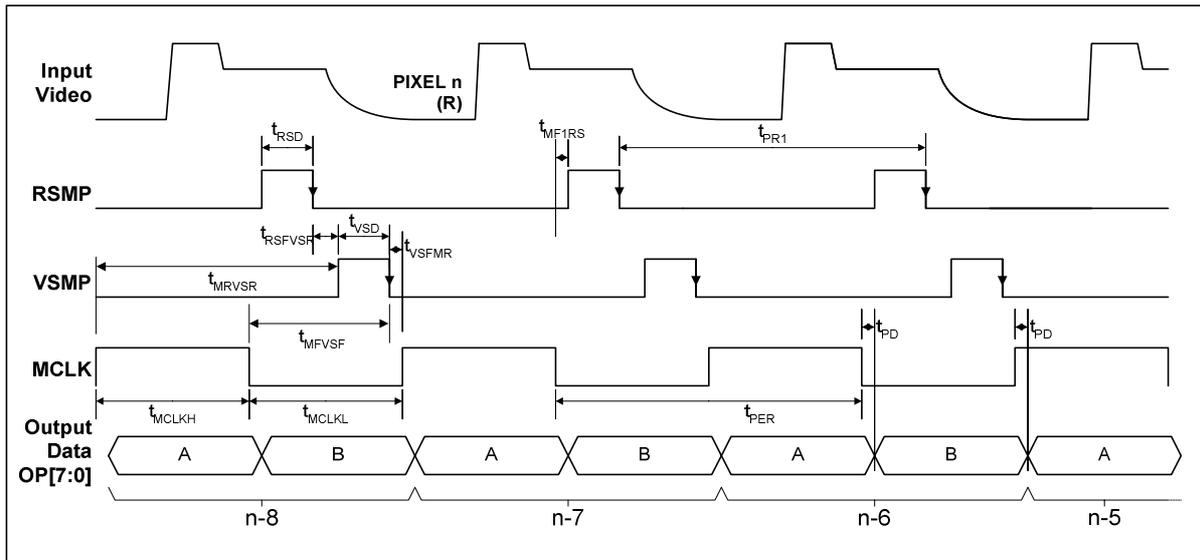


Figure 3 Single-channel CDS Input Video Timing

**Notes:**

1. The relationship between input video and sampling is controlled by VSMP and RSMP.
2. When VSMP is high the input video signal is connected to the Video sampling capacitors.
3. When RSMP is high the input video signal is connected to the Reset sampling capacitors.
4. RSMP must not go high before the first falling edge of MCLK after VSMP goes low.
5. It is required that the falling edge of VSMP should occur before the rising edge of MCLK.
6. In 1-channel CDS mode it is not possible to have a equally spaced Video and Reset sample points with a 24MHz MCLK
7. Non-CDS operation is also possible; RSMP is not required in this mode.

**Test Conditions**

AVDD = DVDD1 = DVDD2 = 3.3V, AGND = DGND = 0V, T<sub>A</sub> = 25°C, MCLK = 24MHz unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
MCLK period	t <sub>PER</sub>		41.6			ns
MCLK high period	t <sub>MCLKH</sub>		18.8	20.8		ns
MCLK low period	t <sub>MCLKL</sub>		18.8	20.8		ns
RSMP pulse high time	t <sub>RSd</sub>		5			ns
VSMP pulse high time	t <sub>VSD</sub>		5			ns
RSMP falling to VSMP rising time	t <sub>RSfVSR</sub>		0			ns
MCLK rising to VSMP rising time	t <sub>MRVSR</sub>		3			ns
MCLK falling to VSMP falling time <sup>2</sup>	t <sub>MFVSF</sub>		5			ns
VSMP falling to MCLK rising time	t <sub>VSFMR</sub>		1			ns
1 <sup>st</sup> MCLK falling edge after VSMP falling to RSMP rising time	t <sub>MF1RS</sub>		1			ns
3-channel mode pixel rate	t <sub>PR3</sub>		125			ns
2-channel mode pixel rate	t <sub>PR2</sub>		83.3			ns
1-channel mode pixel rate	t <sub>PR1</sub>		41.6			ns
Output propagation delay	t <sub>PD</sub>			5	10	ns
Output latency. From 1 <sup>st</sup> rising edge of MCLK after VSMP falling to data output	LAT			7		MCLK periods

**Notes:**

1. Parameters are measured at 50% of the rising/falling edge.
2. In Single-Channel mode, if t<sub>MFVSF</sub> is less than 9.5ns, the output amplitude of the WM8213 will decrease.

## SERIAL INTERFACE

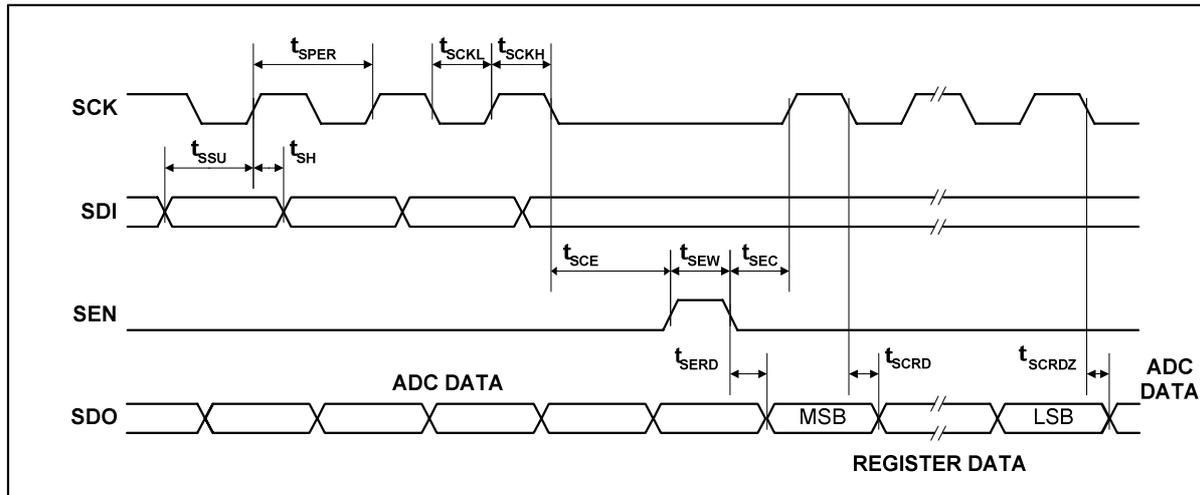


Figure 4 Serial Interface Timing

## Test Conditions

AVDD = DVDD1 = DVDD2 = 3.3V, AGND = DGND = 0V, T<sub>A</sub> = 25°C, MCLK = 24MHz unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
SCK period	t <sub>SPER</sub>		83.3			ns
SCK high	t <sub>SCKH</sub>		37.5			ns
SCK low	t <sub>SCKL</sub>		37.5			ns
SDI set-up time	t <sub>SSU</sub>		6			ns
SDI hold time	t <sub>SH</sub>		6			ns
SCK to SEN set-up time	t <sub>SCE</sub>		12			ns
SEN to SCK set-up time	t <sub>SEC</sub>		12			ns
SEN pulse width	t <sub>SEW</sub>		60			ns
SEN low to SDO = Register data	t <sub>SERD</sub>				30	ns
SCK low to SDO = Register data	t <sub>SCRD</sub>				30	ns
SCK low to SDO = ADC data	t <sub>SCRDZ</sub>				30	ns

## Note:

- Parameters are measured at 50% of the rising/falling edge

## INTERNAL POWER ON RESET CIRCUIT

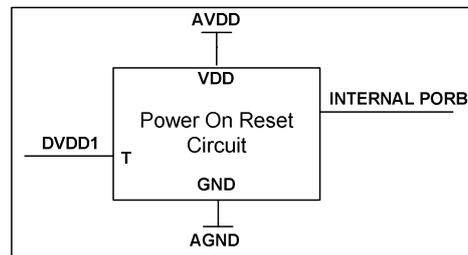


Figure 5 Internal Power On Reset Circuit Schematic

The WM8213 includes an internal Power-On-Reset Circuit, as shown in Figure 5, which is used to reset the digital logic into a default state after power up. The POR circuit is powered from AVDD and monitors DVDD1. It asserts PORB low if AVDD or DVDD1 is below a minimum threshold.

The power supplies can be brought up in any order but it is important that either AVDD is brought up and is stable before DVDD comes up or vice versa as shown in Figure 6 and Figure 7.

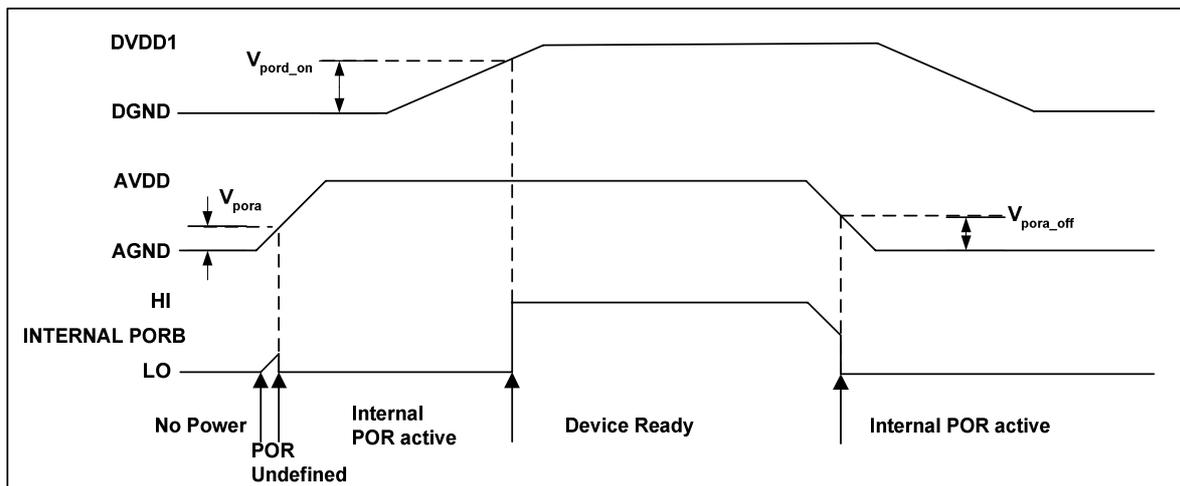


Figure 6 Typical Power up Sequence where AVDD is Powered before DVDD1

Figure 6 shows a typical power-up sequence where AVDD is powered up first. When AVDD rises above the minimum threshold,  $V_{pora}$ , there is enough voltage for the circuit to guarantee PORB is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. Now AVDD is at full supply level. Next DVDD1 rises to  $V_{pord\_on}$  and PORB is released high and all registers are in their default state and writes to the control interface may take place.

On power down, where AVDD falls first, PORB is asserted low whenever AVDD drops below the minimum threshold  $V_{pora\_off}$ .

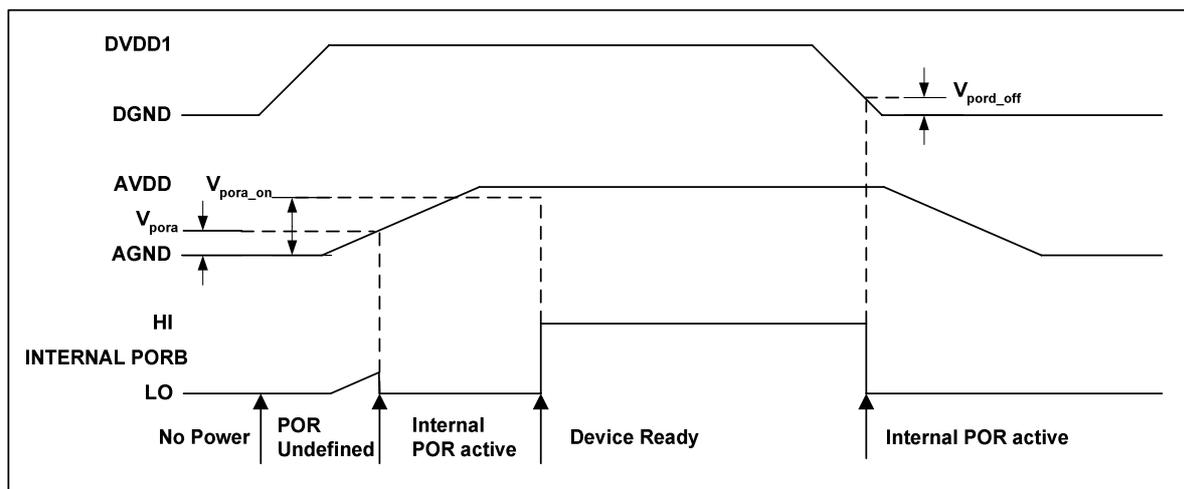


Figure 7 Typical Power up Sequence where DVDD1 is Powered before AVDD

Figure 7 shows a typical power-up sequence where DVDD1 is powered up first. It is assumed that DVDD1 is already up to specified operating voltage. When AVDD goes above the minimum threshold,  $V_{pora}$ , there is enough voltage for the circuit to guarantee PORB is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. When AVDD rises to  $V_{pora\_on}$ , PORB is released high and all registers are in their default state and writes to the control interface may take place.

On power down, where DVDD1 falls first, PORB is asserted low whenever DVDD1 drops below the minimum threshold  $V_{pord\_off}$ .

SYMBOL	TYP	UNIT
$V_{pora}$	0.6	V
$V_{pora\_on}$	1.2	V
$V_{pora\_off}$	0.6	V
$V_{pord\_on}$	0.7	V
$V_{pord\_off}$	0.6	V

Table 1 Typical POR Operation (typical values, not tested)

**Note:** It is recommended that every time power is cycled to the WM8213 a software reset is written to the software register to ensure that the contents of the control registers are at their default values before carrying out any other register writes.

## DEVICE DESCRIPTION

### INTRODUCTION

A block diagram of the device showing the signal path is presented on the front page of this datasheet.

The WM8213 samples up to three inputs (RINP, GINP and BINP) simultaneously. The device then processes the sampled video signal with respect to the video reset level or an internally/externally generated reference level using between one and three processing channels.

Each processing channel consists of an Input Sampling block with optional Reset Level Clamping (RLC) and Correlated Double Sampling (CDS), an 8-bit programmable offset DAC and a 9-bit Programmable Gain Amplifier (PGA).

The ADC then converts each resulting analogue signal to a 16-bit digital word. The digital output from the ADC is presented on an 8-bit wide bus.

On-chip control registers determine the configuration of the device, including the offsets and gains applied to each channel. These registers are programmable via a serial interface.

The WM8213 has been designed to have a high degree of compatibility with previous generations of Wolfson AFEs. By setting the LEGACY register bit the device adopts the same timing as the WM819x and WM815x families of AFEs. The control interface is also compatible.

### INPUT SAMPLING

The WM8213 can sample and process one to three inputs through one to three processing channels as follows:

**Colour Pixel-by-Pixel:** The three inputs (RINP, GINP and BINP) are simultaneously sampled for each pixel and a separate channel processes each input. The signals are then multiplexed into the ADC, which converts all three inputs within the pixel period.

**Two Channel Pixel-by-pixel:** Two input channels (RINP and GINP) are simultaneously sampled for each pixel and a separate channel processes each input. The signals are then multiplexed into the ADC, which converts both inputs within the pixel period. The unused Blue channel is powered down when this mode is selected.

**Monochrome:** A single chosen input (RINP, GINP, or BINP) is sampled, processed by the corresponding channel, and converted by the ADC. The choice of input and channel can be changed via the control interface, e.g. on a line-by-line basis if required. The unused channels are powered down when this mode is selected.

**Colour Line-by-Line:** A single input (RINP) is sampled and multiplexed into the red channel for processing before being converted by the ADC. The registers which are applied to the PGA and Offset DAC can be switched in turn (RINP → GINP → BINP → RINP...) by applying pulses to the RSMP pin. This is known as auto-cycling. Alternatively, other sequences can be generated via the control registers. This mode causes the unused blue and green channels to be powered down. Refer to the Line-by-Line Operation section for more details.

### RESET LEVEL CLAMPING (RLC)

To ensure that the signal applied to the WM8213 lies within the supply voltage range (0V to AVDD) the output signal from a CCD is usually level shifted by coupling through a capacitor,  $C_{IN}$ . The RLC circuit clamps the WM8213 side of this capacitor to a suitable voltage through a CMOS switch during the CCD reset period. In order for clamping to produce sensible results the input voltage during the clamping must be a consistent value.

The WM8213 allows the user to control the RLC switch in a variety of ways as illustrated in Figure 8. This figure shows a single channel, however all 3 channels are identical, each with its own clamp switch controlled by the common CLMP signal.

The method of control chosen depends upon the characteristics of the input video. The RLCEN register bit must be set to 1 to enable clamping, otherwise the RLC switch cannot be closed (by default RLCEN=1).

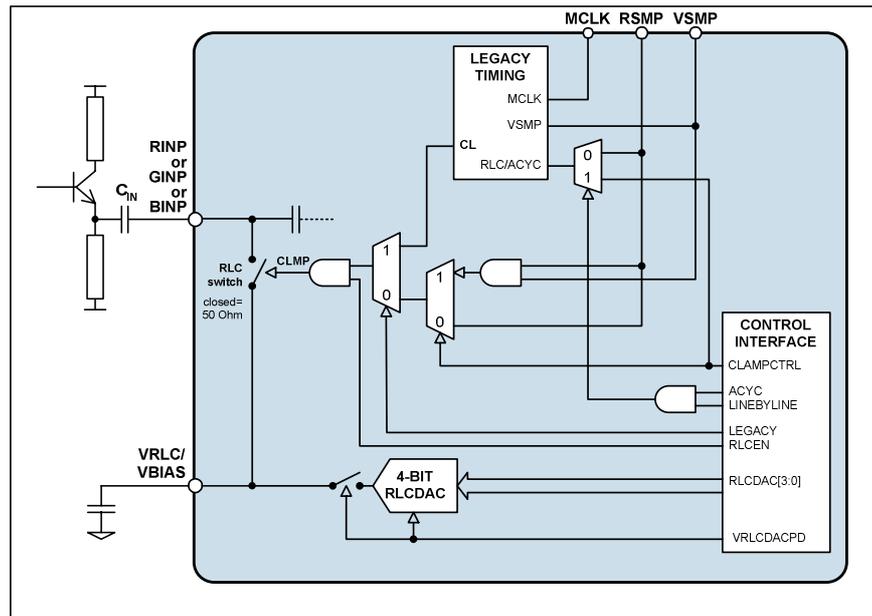


Figure 8 RLC Clamp Control Options

When an input waveform has a stable reference level on every pixel it may be desirable to clamp every pixel during this period. Setting CLAMPCTRL=0 means that the RLC switch is closed whenever the RSMP input pin is high, as shown in Figure 9.

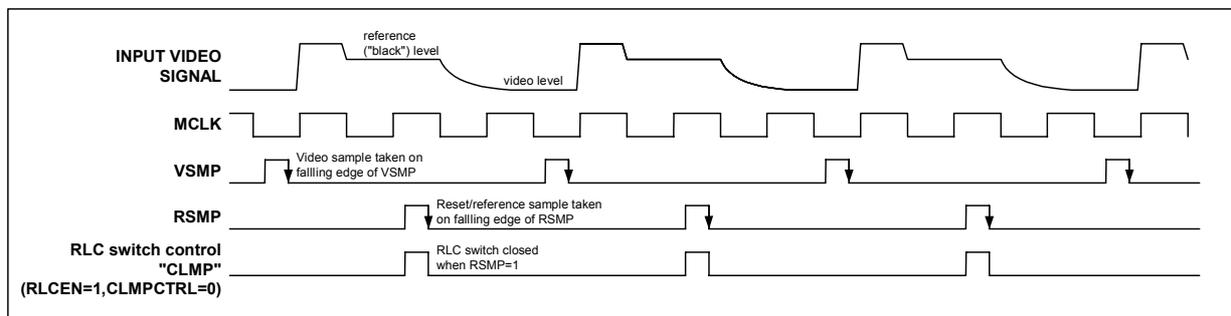


Figure 9 Reset Level Clamp Operation (CLAMPCTRL=0), CDS operation shown, non-CDS also possible

In situations where the input video signal does not have a stable reference level it may be necessary to clamp only during those pixels which have a known state (e.g. the dummy, or "black" pixels at the start or end of a line of most image sensors). This is known as line-clamping and relies on the input capacitor to hold the DC level between clamp intervals. In non-CDS mode (CDS=0) this can be done directly by controlling the RSMP input pin to go high during the black pixels only.

Alternatively it is possible to use RSMP to identify the black pixels and enable the clamp at the same time as the input is being sampled (i.e. when VSMP is high and RSMP is high). This mode is enabled by setting CLAMPCTRL=1 and the operation is shown in Figure 10.

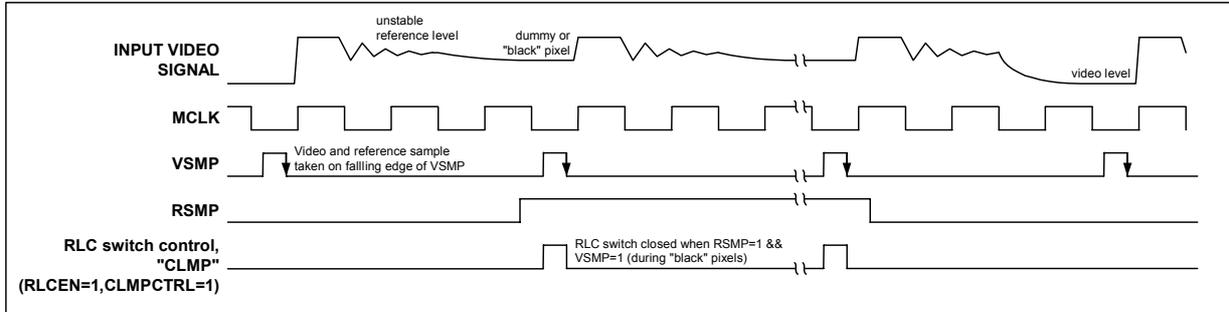


Figure 10 Reset Level Clamp Operation (CLAMPCTRL=1), non-CDS mode only

When in LEGACY mode all timing, including the RLC switch timing, is derived from MCLK and VSMP. MCLK operates at double the ADC conversion rate and VSMP determines the sample rate of the device.

Reset Level Clamping in LEGACY mode is only possible in CDS mode and the time at which the clamp switch is closed is concurrent with the reset sample period, RS, as shown in Figure 11. RLC can be enabled on a pixel by pixel basis under control of the RSMP input pin. If RSMP is high when VSMP is high and is sampled by MCLK then clamping will be enabled for that input sample at the time determined by CDSREF[1:0]. If RSMP is low at this point then the RLC switch will not be closed for that input sample. If RLC is required on every pixel then the RSMP pin can be constantly held high in LEGACY mode.

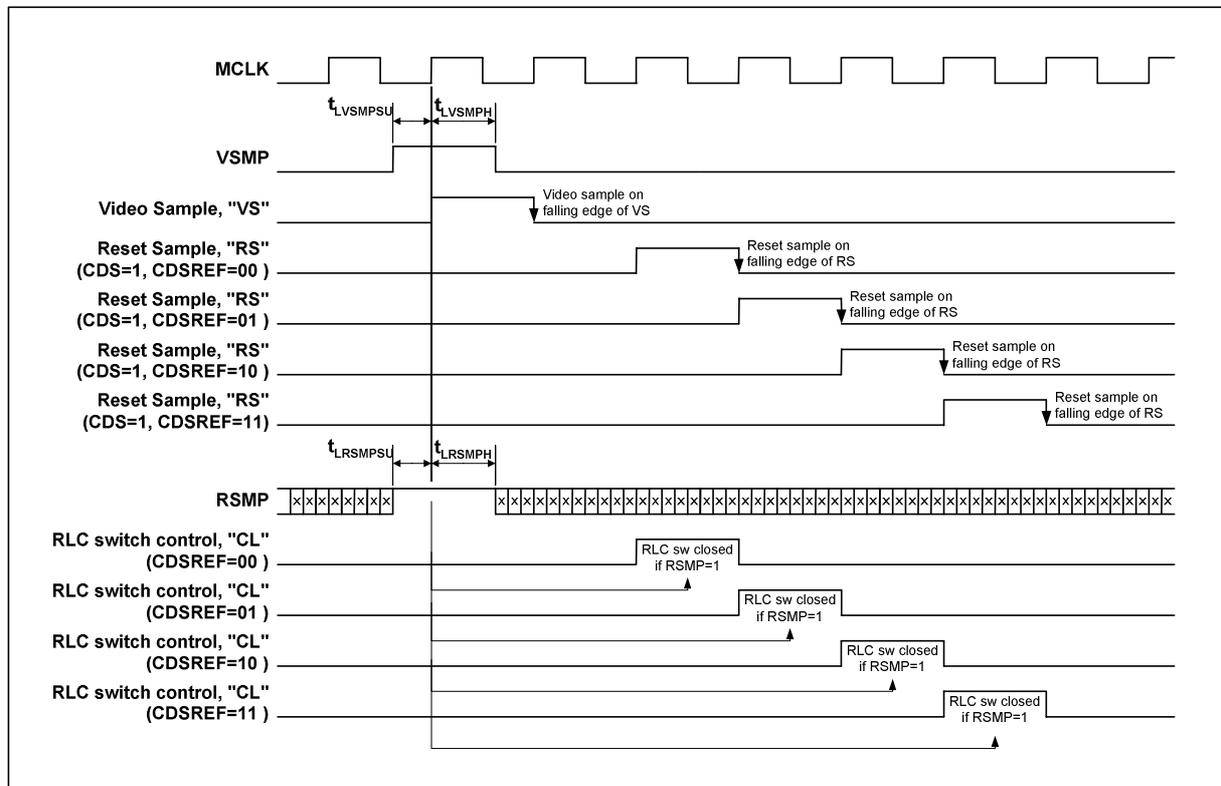


Figure 11 LEGACY Mode RLC and Sampling (LEGACY=1)

Table 2 summarises the various options for control of the Reset Level Clamp switch.

RLCEN	LEGACY	CLAMPCTRL	LINEBYLINE &&ACYC	OUTCOME	USE
0	X	X	X	RLC is not enabled. RLC switch is always open.	When input is DC coupled and within supply rails.
1	0	0	X	RLC switch is controlled directly from RSMP input pin: RSMP=0: switch is open RSMP=1: switch is closed	When user explicitly provides a reset sample signal and the input video waveform has a suitable reset level.
1	0	1	X	VSMP applied as normal, RSMP is used to indicate the location of black pixels RLC switch is controlled by logical combination of RSMP and VSMP: RSMP && VSMP = 0: switch is open RSMP && VSMP = 1: switch is closed	When you wish to clamp during the video period of black pixels or there is no stable per-pixel reference level.
1	1	X	X	LEGACY mode RLC works in the same fashion as the WM819x series, where the RSMP pin is equivalent to the RLC/ACYC pin on those devices. The reset sample clock which is generated by the LEGACY internal timing generator is gated with the RSMP pin to produce the RLC control signal CL (see Figure 11): CL=0: clamp switch open CL=1: clamp switch closed	When using the LEGACY timing mode.
X	1	0	1	In this mode the RSMP pin is used to control auto-cycling so can't be used for clamp control. Register bit CLAMPCTRL controls whether RLC is enabled or not. CLAMPCTRL=0, RLC is disabled CLAMPCTRL=1, RLC is enabled and every pixel will be clamped during the control signal CL (see Figure 11).	When auto-cycling in LEGACY mode.
		1			

Table 2 Reset Level Clamp Control Summary

## CDS/NON-CDS PROCESSING

For CCD type input signals, containing a fixed reference/reset level, the signal may be processed using Correlated Double Sampling (CDS), which will remove pixel-by-pixel common mode noise. With CDS processing the input waveform is sampled at two different points in time for each pixel, once during the reference/reset level and once during the video level. To sample using CDS, register bit CDS must be set to 1 (default). This causes the signal reference to come from the video reference level as shown in Figure 12.

The video sample is always taken on the falling edge of the input VSMP signal (VS). In CDS-mode the reset level is sampled on the falling edge of the RSMP input signal (RS).

For input signals that do not contain a reference/reset level (e.g. CIS sensor signals), non-CDS processing is used (CDS=0). In this case, the video level is processed with respect to the voltage on pin VRLC/VBIAS. The VRLC/VBIAS voltage is sampled at the same time as VSMP samples the video level in this mode.

In LEGACY mode the input video signal is always sampled on the 1<sup>st</sup> rising edge of MCLK after VSMP has gone low (VS) regardless of the operating mode. If in non-CDS mode (CDS=0) the voltage on the VRLC/VBIAS pin is also sampled at this point. In CDS-mode (CDS=1) the position of the reset sample (RS) can be varied, under control of the CDSREF[1:0] register bits, as shown in Figure 11.

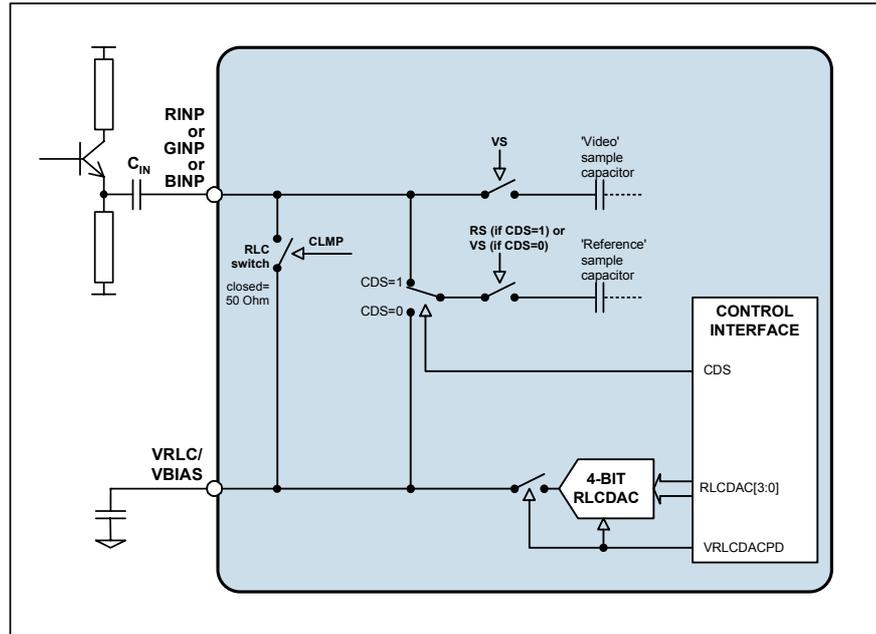


Figure 12 CDS/non-CDS Input Configuration

## OFFSET ADJUST AND PROGRAMMABLE GAIN

The output from the CDS block is a differential signal, which is added to the output of an 8-bit Offset DAC to compensate for offsets and then amplified by a 9-bit PGA. The gain and offset for each channel are independently programmable by writing to control bits DAC[7:0] and PGA[7:0].

The gain characteristic of the WM8213 PGA is shown in Figure 13. Figure 14 shows the maximum device input voltage that can be gained up to match the ADC full-scale input range (default=2V).

In colour line-by-line mode the gain and offset coefficients for each colour can be multiplexed in order (Red → Green → Blue → Red...) by pulsing the RSMP pin, or controlled via the ACYC and INTM[1:0] bits. Refer to the Line-by-Line Operation section for more details.

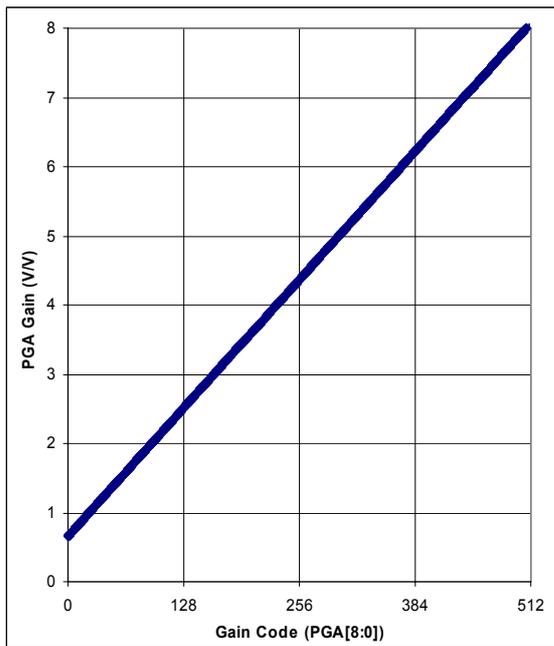


Figure 13 PGA Gain Characteristic

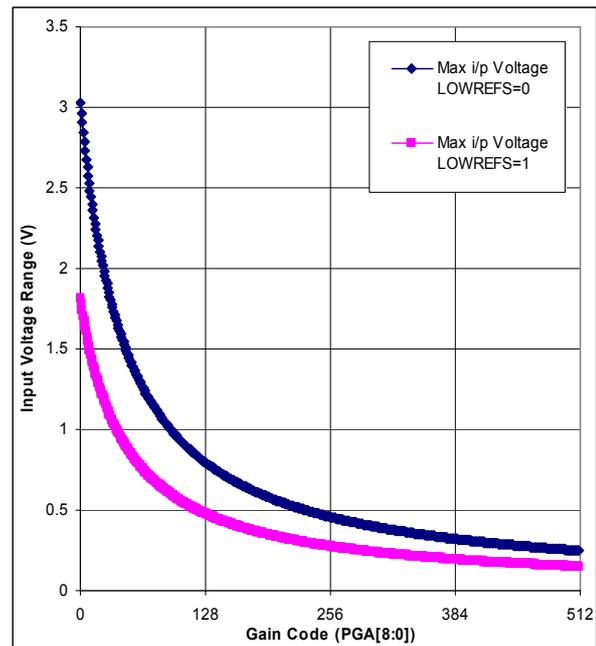


Figure 14 Peak Input Voltage to Match ADC Full-scale Range

## ADC INPUT BLACK LEVEL ADJUST

The output from the PGA can be offset to match the full-scale range of the differential ADC ( $2 \times [VRT-VRB]$ ).

For negative-going input video signals, a black level (zero differential) output from the PGA should be offset to the top of the ADC range by setting register bits PGAFS[1:0]=10. This will give an output code of FFFF (hex) from the WM8213 for zero input. If code zero is required for zero differential input then the INVOP bit should be set.

For positive going input signals the black level should be offset to the bottom of the ADC range by setting PGAFS[1:0]=11. This will give an output code of 0000 (hex) from the WM8213 for zero input.

Bipolar input video is accommodated by setting PGAFS[1:0]=00 or PGAFS[1:0]=01. Zero differential input voltage gives mid-range ADC output, 7FFF (hex).

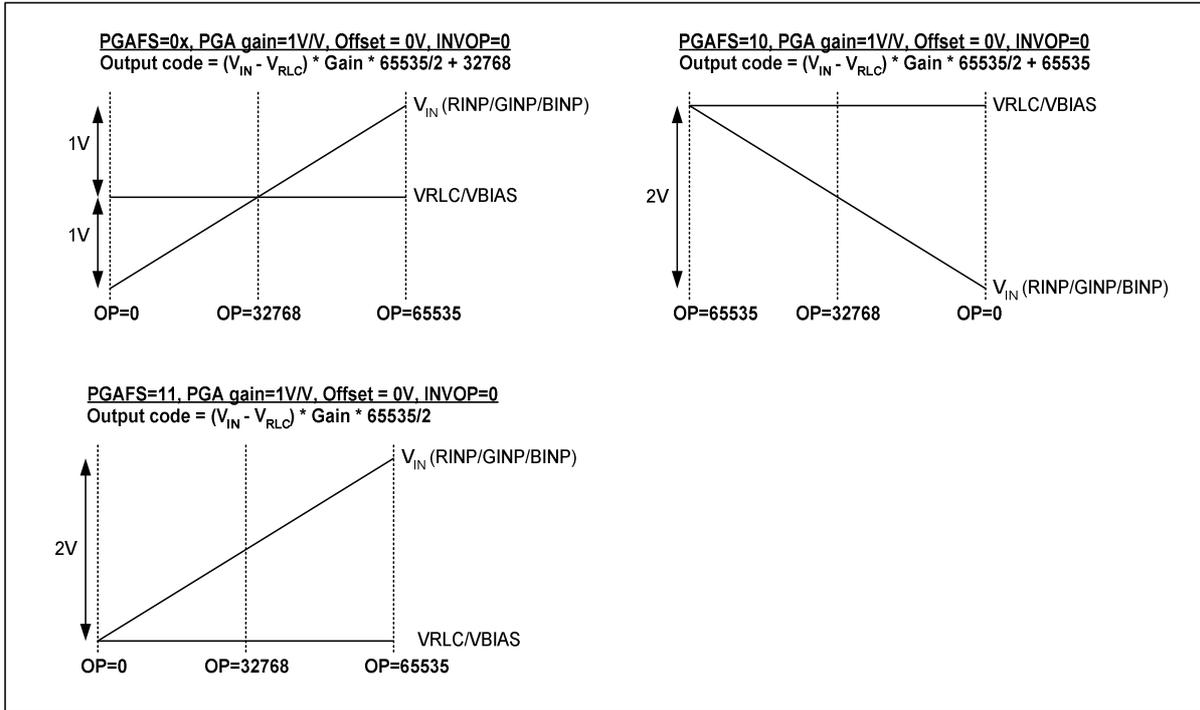


Figure 15 ADC Input Black Level Adjust Settings

OVERALL SIGNAL FLOW SUMMARY

Figure 16 represents the processing of the video signal through the WM8213.

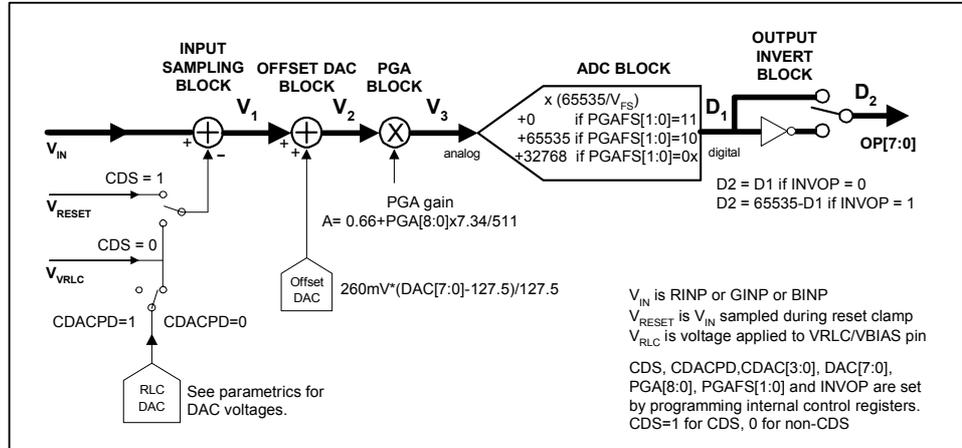


Figure 16 Overall Signal Flow

The **INPUT SAMPLING BLOCK** produces an effective input voltage  $V_1$ . For CDS, this is the difference between the input video level  $V_{IN}$  and the input reset level  $V_{RESET}$ . For non-CDS this is the difference between the input video level  $V_{IN}$  and the voltage on the VRLC/VBIAS pin,  $V_{VRLC}$ , optionally set via the RLC DAC.

The **OFFSET DAC BLOCK** then adds the amount of fine offset adjustment required to move the black level of the input signal towards 0V, producing  $V_2$ .

The **PGA BLOCK** then amplifies the white level of the input signal to maximise the ADC range, outputting voltage  $V_3$ .

The **ADC BLOCK** then converts the analogue signal,  $V_3$ , to a 16-bit unsigned digital output,  $D_1$ .

The digital output is then inverted, if required, through the **OUTPUT INVERT BLOCK** to produce  $D_2$ .

## CALCULATING THE OUTPUT CODE FOR A GIVEN INPUT

The following equations describe the processing of the video and reset level signals through the WM8213. The values of  $V_1$ ,  $V_2$  and  $V_3$  are often calculated in reverse order during device setup. The PGA value is written first to set the input Voltage range, the Offset DAC is then adjusted to compensate for any Black/Reset level offsets and finally the RLC DAC value is set to position the reset level correctly during operation.

**Note:** Refer to Applications Note WAN0123 for detailed information on device calibration procedures.

### INPUT SAMPLING BLOCK: INPUT SAMPLING AND REFERENCING

If CDS = 1, (i.e. CDS operation) the previously sampled reset level,  $V_{\text{RESET}}$ , is subtracted from the input video.

$$V_1 = V_{\text{IN}} - V_{\text{RESET}} \quad \text{Eqn. 1}$$

If CDS = 0, (non-CDS operation) the simultaneously sampled voltage on pin VR<sub>LC</sub> is subtracted instead.

$$V_1 = V_{\text{IN}} - V_{\text{VRLC}} \quad \text{Eqn. 2}$$

If VRLCDACPD = 1,  $V_{\text{VRLC}}$  is an externally applied voltage on pin VR<sub>LC</sub>/VBIAS.

If VRLCDACPD = 0,  $V_{\text{VRLC}}$  is the output from the internal RLC DAC.

$$V_{\text{VRLC}} = (V_{\text{RLCSTEP}} * \text{RLC DAC}[3:0]) + V_{\text{RLCBOT}} \quad \text{Eqn. 3}$$

$V_{\text{RLCSTEP}}$  is the step size of the RLC DAC and  $V_{\text{RLCBOT}}$  is the minimum output of the RLC DAC.

### OFFSET DAC BLOCK: OFFSET (BLACK-LEVEL) ADJUST

The resultant signal  $V_1$  is added to the Offset DAC output.

$$V_2 = V_1 + \{260\text{mV} * (\text{DAC}[7:0] - 127.5)\} / 127.5 \quad \text{Eqn. 4}$$

### PGA NODE: GAIN ADJUST

The signal is then multiplied by the PGA gain.

$$V_3 = V_2 * (0.66 + \text{PGA}[8:0] * 7.34/511) \quad \text{Eqn. 5}$$

### ADC BLOCK: ANALOGUE-DIGITAL CONVERSION

The analogue signal is then converted to a 16-bit unsigned number, with input range configured by PGAFS[1:0].

$$D_1[15:0] = \text{INT}\{ (V_3 / V_{\text{FS}}) * 65535\} + 32767 \quad \text{PGAFS}[1:0] = 00 \text{ or } 01 \quad \text{Eqn. 6}$$

$$D_1[15:0] = \text{INT}\{ (V_3 / V_{\text{FS}}) * 65535\} \quad \text{PGAFS}[1:0] = 11 \quad \text{Eqn. 7}$$

$$D_1[15:0] = \text{INT}\{ (V_3 / V_{\text{FS}}) * 65535\} + 65535 \quad \text{PGAFS}[1:0] = 10 \quad \text{Eqn. 8}$$

where the ADC full-scale range,  $V_{\text{FS}} = 2\text{V}$  when LOWREFS=0 and  $V_{\text{FS}} = 1.2\text{V}$  when LOWREFS=1.

### OUTPUT INVERT BLOCK: POLARITY ADJUST

The polarity of the digital output may be inverted by control bit INVOP.

$$D_2[15:0] = D_1[15:0] \quad (\text{INVOP} = 0) \quad \text{Eqn. 9}$$

$$D_2[15:0] = 65535 - D_1[15:0] \quad (\text{INVOP} = 1) \quad \text{Eqn. 10}$$

## OUTPUT FORMATS

The output from the WM8213 can be presented in several different formats under control of the OPFORM[1:0] register bits as shown in Figure 17.

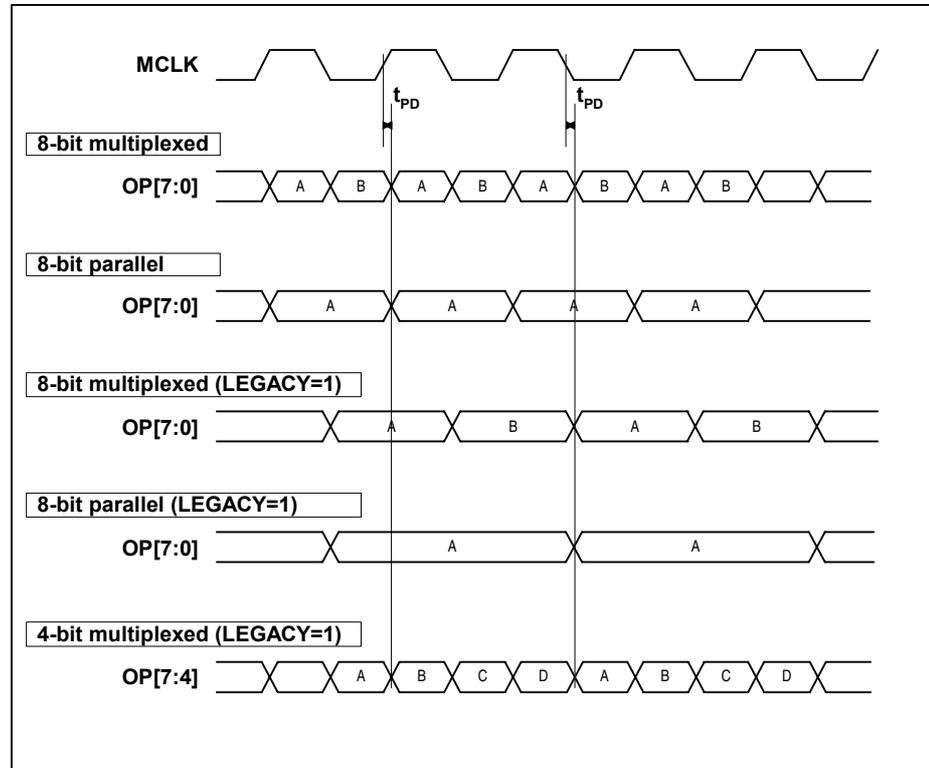


Figure 17 Output Data Formats

OUTPUT FORMAT	OPFORM[1:0]	LEGACY	OUTPUT PINS	OUTPUT
8+8-bit multiplexed	00, 10	X	OP[7:0]	A = d15, d14, d13, d12, d11, d10, d9, d8 B = d7, d6, d5, d4, d3, d2, d1, d0
8-bit parallel	01	X	OP[7:0]	A = d15, d14, d13, d12, d11, d10, d9, d8
4+4+4+4-bit (nibble)	11	1	OP[7:4]	A = d15, d14, d13, d12 B = d11, d10, d9, d8 C = d7, d6, d5, d4 D = d3, d2, d1, d0

Table 3 Details of Output Data Formats (as shown in Figure 17).

## REFERENCES

The ADC reference voltages are derived from an internal bandgap reference, and buffered to pins VRT and VRB, where they must be decoupled to ground. Pin VRX is driven by a similar buffer, and also requires decoupling. The output buffer from the RLCDAC also requires decoupling at pin VRLC/VBIAS.

## POWER MANAGEMENT

Power management for the device is performed via the Control Interface. By default the device is fully enabled. The EN bit allows the device to be fully powered down when set low. Individual blocks can be powered down using the bits in Setup Register 5. When in MONO or TWOCHAN mode the unused input channels are automatically disabled to reduce power consumption.

## LINE-BY-LINE OPERATION

Certain linear sensors give colour output on a line-by-line basis. i.e. a full line of red pixels followed by a line of green pixels followed by a line of blue pixels. Often the sensor will have only a single output onto which these outputs are time multiplexed.

The WM8213 can accommodate this type of input by setting the LINEBYLINE register bit high. When in this mode the green and blue input PGAs are disabled to save power. The analogue input signal should be connected to the RINP pin. The offset and gain values that are applied to the Red input channel can be selected, by internal multiplexers, to come from the Red, Green or Blue offset and gain registers. This allows the gain and offset values for each of the input colours to be setup individually at the start of a scan.

When register bit ACYC=0 the gain and offset multiplexers are controlled via the INTM[1:0] register bits. When INTM=00 the red offset and gain control registers are used to control the Red input channel, INTM=01 selects the green offset and gain registers and INTM=10 selects the blue offset and gain registers to control the Red input channel.

When register bit ACYC=1, 'auto-cycling' is enabled, and the input channel switches to the next offset and gain registers in the sequence when a pulse is applied to the RSMP input pin. The sequence is Red → Green → Blue → Red... offset and gain registers applied to the single input channel. A write to the Auto-cycle reset register (address 05h) will reset the sequence to a known state (Red registers selected).

When auto-cycling is enabled, the RSMP pin cannot be used to control reset level clamping. The CLMPCTRL bit may be used instead (enabled when high, disabled when low).

NB, when auto-cycling is enabled, the RSMP pin cannot be used for reset sampling (i.e. CDS must be set to 0).

## CONTROL INTERFACE

The internal control registers are programmable via the serial digital control interface. The register contents can be read back via the serial interface on pin OP[7]/SDO.

**Note:** It is recommended that a software reset is carried out after the power-up sequence, before writing to any other register. This ensures that all registers are set to their default values (as shown in Table 7).

### SERIAL INTERFACE: REGISTER WRITE

Figure 18 shows register writing in serial mode. Three pins, SCK, SDI and SEN are used. A six-bit address (a5, 0, a3, a2, a1, a0) is clocked in through SDI, MSB first, followed by an eight-bit data word (b7, b6, b5, b4, b3, b2, b1, b0), also MSB first. Each bit is latched on the rising edge of SCK. When the data has been shifted into the device, a pulse is applied to SEN to transfer the data to the appropriate internal register. Note all valid registers have address bit a4 equal to 0 in write mode.

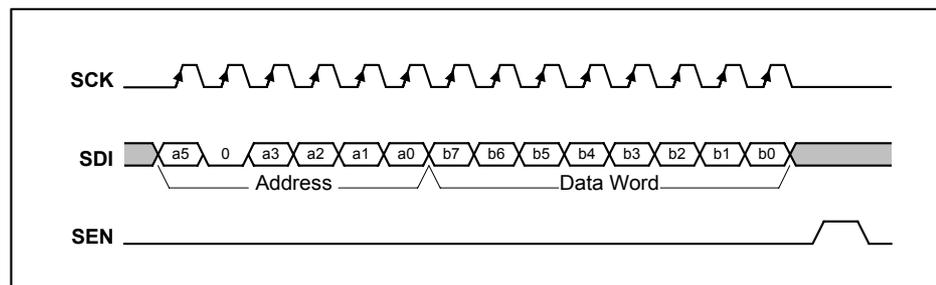
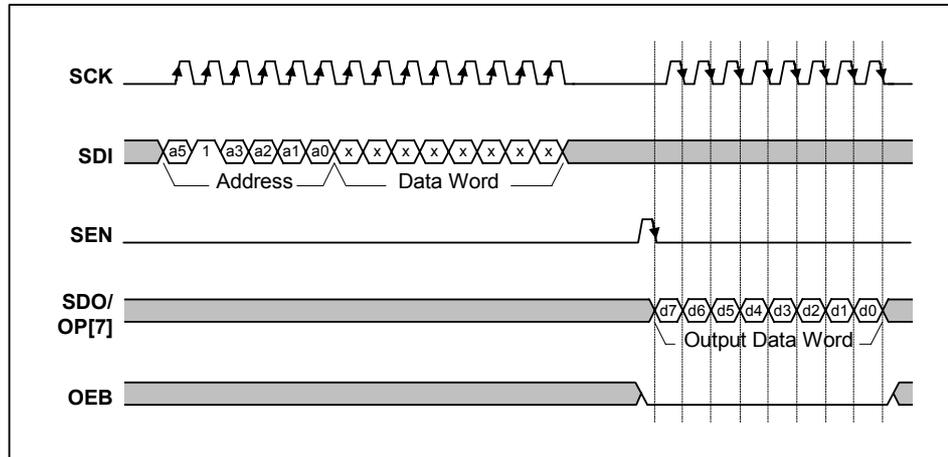


Figure 18 Serial Interface Register Write

A software reset is carried out by writing to Address "000100" with any value of data, (i.e. Data Word = XXXXXXXX).

**SERIAL INTERFACE: REGISTER READ-BACK**

Figure 19 shows register read-back in serial mode. Read-back is initiated by writing to the serial bus as described above but with address bit a4 set to 1, followed by an 8-bit dummy data word. Writing address (a5, 1, a3, a2, a1, a0) will cause the contents (d7, d6, d5, d4, d3, d2, d1, d0) of corresponding register (a5, 0, a3, a2, a1, a0) to be output MSB first on pin SDO (on the falling edge of SCK). Note that pin SDO is shared with an output pin, OP[7], therefore OEB should always be held low and the OPD register bit should be set low when register read-back data is expected on this pin. The next word may be read in to SDI while the previous word is still being output on SDO.



**Figure 19 Serial Interface Register Read-back**

## NORMAL OPERATING MODES

Table 4 below shows the normal operating modes of the device. The MCLK speed can be specified along with the MCLK:VSMP ratio to achieve the desired sample rate.

NUMBER OF CHANNELS	DESCRIPTION	CDS AVAILABLE	MAXIMUM SAMPLE RATE	TIMING REQUIREMENTS	CHANNEL MODE SETTINGS
3	Three channel Pixel-by-Pixel	YES	8 MSPS	MCLK max = 24MHz Minimum MCLK:VSMP ratio = 3:1	MONO = 0 TWOCHAN = 0
2	Two channel Pixel-by-Pixel	YES	12 MSPS	MCLK max = 24MHz Minimum MCLK:VSMP ratio = 2:1	MONO = 0 TWOCHAN = 1
1	One channel Pixel-by-Pixel	YES	24 MSPS	MCLK max = 24MHz Minimum MCLK:VSMP ratio = 1:1	MONO = 1 TWOCHAN = 0

**Table 4 WM8213 Normal Operating Modes**

Table 5 below shows the different channel mode register settings required to operate the 8213 in 1, 2 and 3 channel modes.

MONO	TWOCHAN	CHAN[1:0]	MODE DESCRIPTION
0	0	XX	3-channel (colour mode)
0	1	XX	2-channel (Blue PGA disabled)
1	0	00	1-channel (monochrome) mode. Red channel selected, Green and Blue PGAs disabled.
1	0	01	1-channel (monochrome) mode. Green channel selected, Red and Blue PGAs disabled.
1	0	10	1-channel (monochrome) mode. Blue channel selected, Red and Green PGAs disabled.
1	0	11	Invalid mode
1	1	XX	Invalid mode

**Table 5 Sampling Mode Summary**

**Note:** Unused input pins should be connected to AGND.