

INTRODUCTION

The CCD201 is a large format sensor (> 1k²) in the L3Vision™ range of products from e2v technologies. This device uses a novel output amplifier circuit that is capable of operating at an equivalent output noise of less than one electron at pixel rates of over 15 MHz. This makes the sensor well suited for scientific imaging where the illumination is limited.

The sensor is a frame transfer device and can operate in inverted mode to suppress dark current as this is now the dominant noise source (even at high readout rate). The image and store sections are designed to operate in 2-phase mode, to maximise the highest achievable parallel transfer frequency.

The sensor functions by converting photons to charge in the image area during the integration time period, then transferring this charge through the image and store sections into the readout register. Following transfer through the readout register, the charge is multiplied in the gain register before conversion to a voltage by an output amplifier.

The sensor has two output amplifiers; a low noise, high responsivity output for normal CCD operation and a large signal amplifier for when multiplication gain is employed.

Operation of the high gain mode is controlled by adjustment of the multiplication phase amplitude RØ2HV.

GENERAL DATA

Active image area	13.3 x 13.3 mm
Image section active pixels	1024 (H) x 1024 (V)
Image pixel size	13 x 13 µm
Number of output amplifiers	2
Fill factor	100%
Additional dark reference columns	32
Additional overscan rows	8

PACKAGE DETAILS (see Fig. 15)

Ceramic Package

Overall dimensions	37.4 x 26.5 mm
Number of pins	36
Inter-pin spacing	2.54 mm
Mounting position	any

The pin 1 marker is shown in Fig. 15.

STORAGE AND OPERATION TEMPERATURE EXTREMES

	MIN	MAX
Storage temperature (°C)	-200	+100
Operating temperature (°C)	-120	+75
Temperature ramping (°C/min)	-	5

Note: Operation or storage in humid conditions may give rise to moisture on the sensor surface on cooling, causing irreversible damage.

TYPICAL PERFORMANCE SPECIFICATIONS

Except where otherwise specified, the following are measured for operation at a pixel rate of 15 MHz, with typical operating voltages. Parameters are given at 223 K unless specified otherwise. Where parameters are different in the normal and high gain mode, both are given.

PARAMETER	UNIT	MIN	TYPICAL	MAX
Output amplifier responsivity, HR amplifier (normal mode) (see note 1)	$\mu\text{V}/\text{e}^-$	-	5.3	-
Output amplifier responsivity, LS amplifier (normal mode) (see note 1)	$\mu\text{V}/\text{e}^-$	-	1.4	-
Multiplication register gain, LS amplifier (high gain mode) (see notes 2, 3 and 4)		1	-	1000
Peak signal - 2-phase IMO	e^-/pixel	50k	80k	-
Charge handling capacity of multiplication register (see note 5)	e^-/pixel	-	730k	-
Charge handling capacity of HR amplifier (see note 6)	e^-	-	280k	-
Charge handling capacity of LS amplifier (see note 6)	e^-	-	1M	-
Readout noise at 50 kHz with CDS, HR amplifier (normal mode) (see note 6)	$\text{e}^- \text{ rms}$	-	3.1	-
Readout noise at 1 MHz with CDS, HR amplifier (normal mode) (see note 6)	$\text{e}^- \text{ rms}$	-	6.0	-
Amplifier reset noise (without CDS), HR amplifier (normal mode) (see note 6)	$\text{e}^- \text{ rms}$	-	50	-
Readout noise at 15 MHz with CDS, LS amplifier (normal mode) (see note 6)	$\text{e}^- \text{ rms}$	-	43	-
Amplifier reset noise (without CDS), LS amplifier (normal mode) (see note 6)	$\text{e}^- \text{ rms}$	-	100	-
Readout noise at 1 MHz (high gain mode) (see note 6)	$\text{e}^- \text{ rms}$	-	< 1	-
Maximum frequency (settling to 1%), HR amplifier (see notes 6 and 7)	MHz	-	-	3
Maximum frequency (settling to 5%), HR amplifier (see notes 6 and 7)	MHz	-	-	4.5
Maximum frequency (settling to 1%), LS amplifier (see note 6 and 7)	MHz	-	-	13
Maximum frequency (settling to 5%), LS amplifier (see note 6 and 7)	MHz	-	-	20
Maximum parallel transfer frequency (see note 1)	MHz	-	0.9	-
Dark signal at 293 K (see note 8)	$\text{e}^-/\text{pixel}/\text{s}$	-	260	530
Dark signal non-uniformity (DSNU) at 293 K (see note 9)	$\text{e}^-/\text{pixel}/\text{s}$	-	90	-
Excess noise factor (see note 10)		-	$\sqrt{2}$	-

NOTES

1. Measured at a pixel rate of 1 MHz.
2. The typical variation of gain with $R\varnothing 2\text{HV}$ is shown in Fig. 1.
3. The variation of gain with $R\varnothing 2\text{HV}$ at different temperatures is shown in Fig. 1.
4. Some increase of $R\varnothing 2\text{HV}$ may be required throughout life to maintain gain performance. Adjustment of $R\varnothing 2\text{HV}$ should be limited to the maximum specified under Operating Conditions.
5. When multiplication gain is used and clock timings optimised, a linear response of output signal with input signal of better than 3% is achieved for output signals up to 400 ke^- typically.
6. These values are inferred by design and not measured.
7. The quoted maximum frequencies assume a 20 pF load and that correlated double sampling is being implemented.
8. The quoted dark signal has the usual temperature dependence for inverted mode operation. For operation at high frame rates with short integration times, there will also be a component generated during readout through the register. Operating at a temperature of 293 K and 10 Hz frame rate, the readout component contributes $5.8 \text{ e}^-/\text{pixel}/\text{frame}$ typically, at a gain of 1000 and referenced to the image area, and has a temperature dependence consistent with non-inverted mode operation.
There exists a further weakly temperature dependent component, the clock induced charge, which is independent of the integration time. The clock induced charge is dependent on the operating biases and timings employed and is typically $0.2 \text{ e}^-/\text{pixel}/\text{frame}$ at $T = -55 \text{ }^\circ\text{C}$.
For more information, refer to the technical note "Dark Signal and Clock-Induced Charge in L3Vision™ CCD Sensors".
9. DSNU is defined as the 1σ variation of the dark signal.
10. The excess noise factor is defined as the factor by which the multiplication process increases the shot noise on the image when multiplication gain is used.

DEVICE COSMETIC PERFORMANCE

Grade 1 devices are supplied to the blemish specification shown below.

Note that incorrect biasing of the device may result in spurious dark or white blemishes appearing. These will be eliminated if the biases are adjusted.

Test Conditions

Operating mode	Devices run in 2-phase inverted mode, with an integration time of 100 ms and a readout rate of 15 MHz.
Sensor temperature	18 ± 3 °C.
Multiplication gain	Set to approximately 1000.
Illumination	Set to give a signal level of approximately $60 e^-$ /pixel/frame.

BLEMISH SPECIFICATION

Black Columns Black defects are counted when they have a responsivity of less than 80% of the local mean signal at approximately the specified multiplication gain and level of illumination. A black column contains at least 9 contiguous black defects.

White Columns White defects are pixels having a dark signal generation rate corresponding to an output signal of greater than 5 times the maximum specified dark signal level. A white column contains at least 9 contiguous white defects.

Pin-Head Columns Pin-head columns are manifest as a partial dark column with a bright pixel showing photoresponse at the end of the column nearest to the readout register. Pin-head columns are counted when the black column has a responsivity of less than 80% of the local mean signal at approximately the specified multiplication gain and level of illumination. A pin-head column contains at least 9 contiguous black defects.

SPECIFICATION

PARAMETER	GRADE 1 SPECIFICATION	GRADE 2 SPECIFICATION
White Columns	0	0
Black /Pin-head Columns	1	6

ORDERING INFORMATION

PART NUMBER	OPERATING MODE	COATING	WINDOW
CCD201-20-* - 122	2-phase	Midband	Temporary

* denotes grade of device.

Figure 1: TYPICAL VARIATION OF MULTIPLICATION GAIN WITH $R_{\text{O}2\text{HV}}$ AT DIFFERENT TEMPERATURES

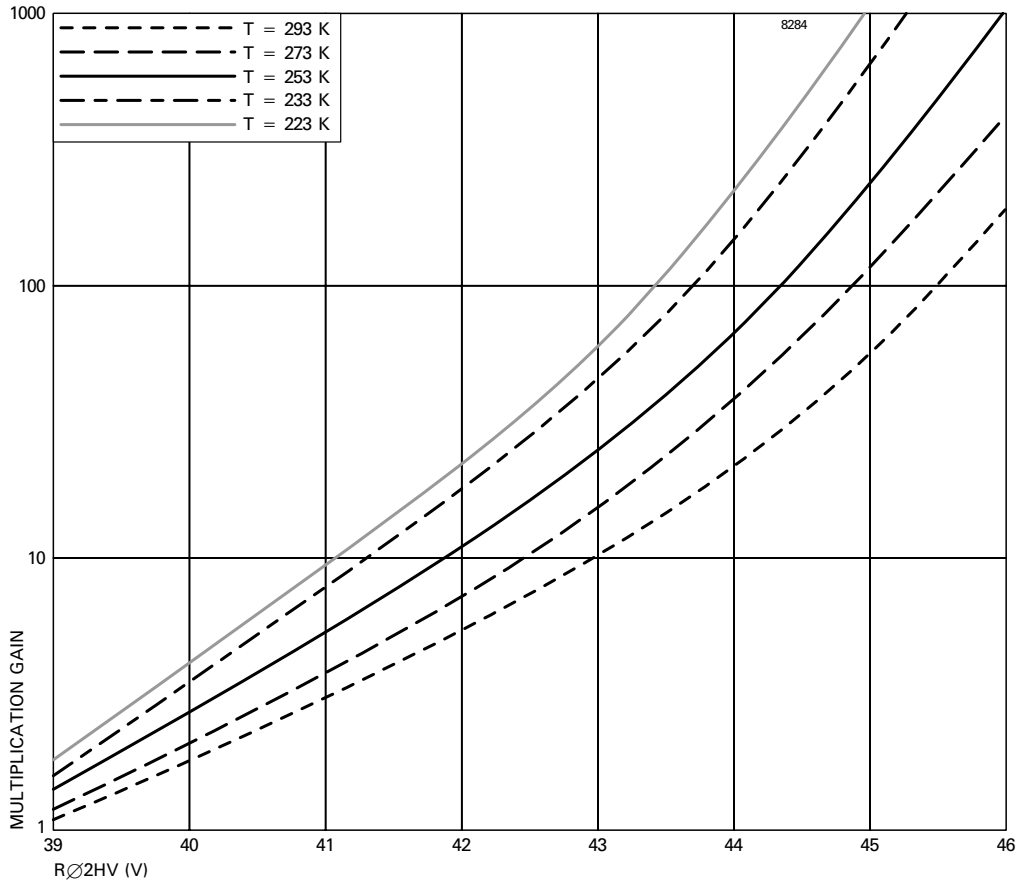


Figure 2: TYPICAL VARIATION OF DARK SIGNAL WITH TEMPERATURE

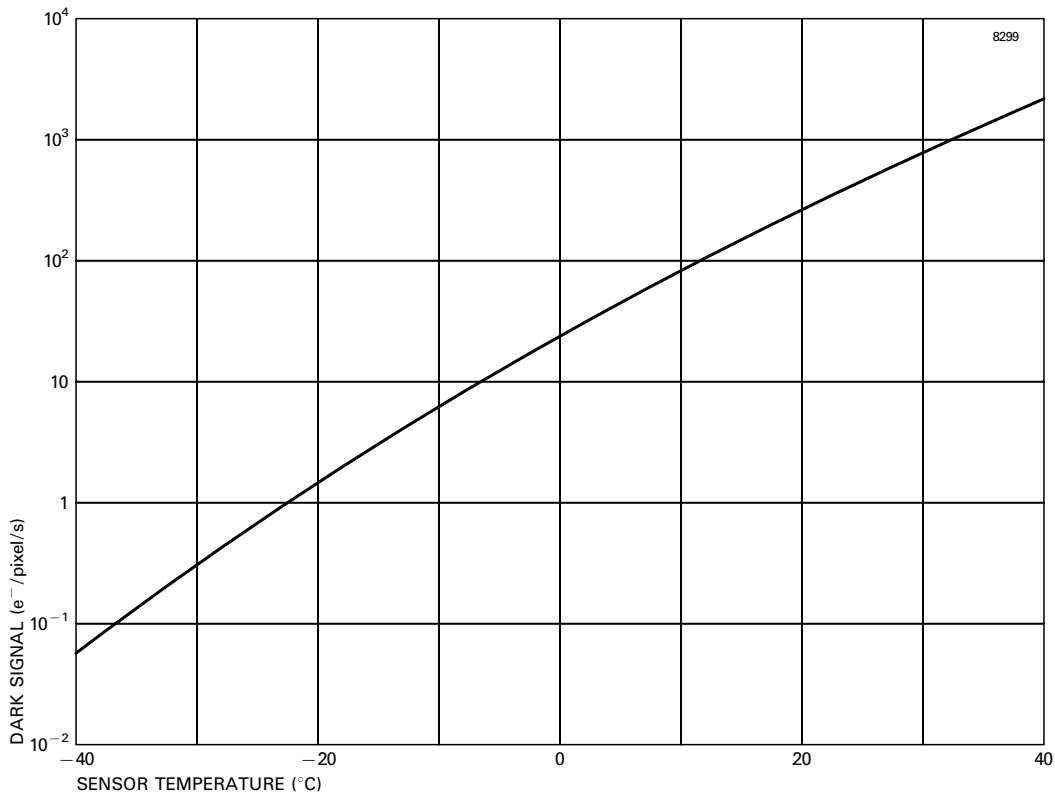
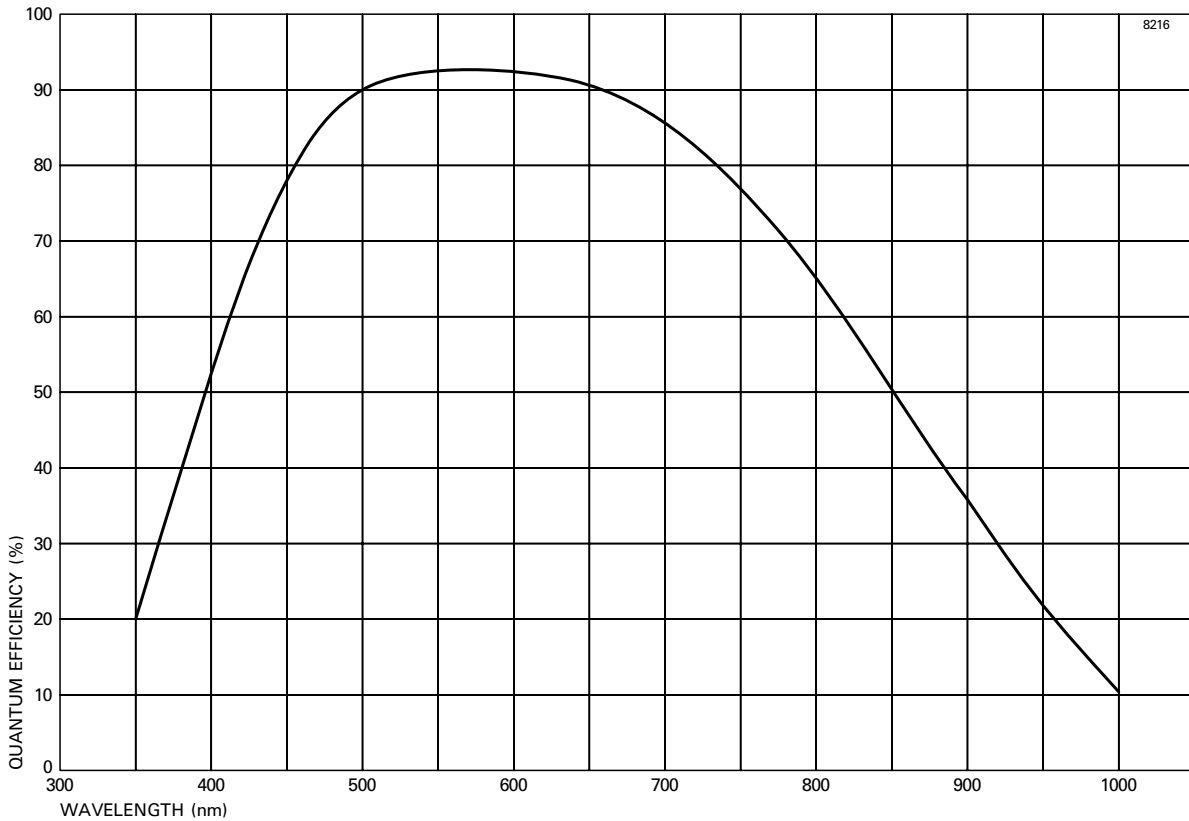


Figure 3: TYPICAL SPECTRAL RESPONSE (At $-20\text{ }^{\circ}\text{C}$, no window, midband coating)



ESD HANDLING PROCEDURES

CCD sensors, in common with most high performance IC devices, are static sensitive. In certain cases a static electricity discharge may destroy or irreversibly degrade the device. Accordingly, full anti-static handling precautions should be taken whenever using a CCD sensor or module. These include:

- Working at a fully grounded workbench.
- Operator wearing a grounded wrist strap.
- All receiving socket pins to be positively grounded.
- Unattended CCDs should not be left out of their conducting foam or socket.

All devices are provided with internal protection circuits to most gate electrodes but not to the other pins.

Evidence of incorrect handling will terminate the warranty.

EXPOSURE TO RADIATION

Exposure to radiation may irreversibly damage the device and result in degradation of performance. Users wishing to operate the device in a radiation environment are advised to consult e2v technologies.

ABSOLUTE MAXIMUM RATINGS

Maximum ratings are with respect to SS.

PIN	CONNECTION	DESCRIPTION	MIN (V)	MAX (V)
1	ABD	Anti-blooming Drain (see note 11)	-0.3	+25
2	SS	Substrate	0	
3	IØ4	Image Clock 4	-20	+20
4	IØ3	Image Clock 3	-20	+20
5	SØ4	Store Clock 4	-20	+20
6	SØ2	Store Clock 2	-20	+20
7	SS	Substrate	0	
8	SS	Substrate	0	
9	DG	Dump Gate	-20	+20
10	OG	Output Gate	-20	+20
11	ODH	Output Drain (HR Amplifier)	-0.3	+32
12	RD	Reset Drain	-0.3	+25
13	ODL	Output Drain (LS Amplifier)	-0.3	+32
14	SS	Substrate	0	
15	OSH	Output Source (HR Amplifier) (see note 12)	-0.3	+25
16	OSL	Output Source (LS Amplifier) (see note 12)	-0.3	+25
17	ØR	Reset Pulse	-20	+20
18	RØDC	Multiplication Register DC Bias	-20	+20
19	RØ2HV	Multiplication Register Clock	-20	+50
20	DG	Dump Gate	-20	+20
21	n.c.	Not Connected		
22	n.c.	Not Connected		
23	SS	Substrate	0	
24	n.c.	Not Connected		
25	n.c.	Not Connected		
26	DD	Dump Drain	-0.3	+25
27	RØ3	Register Clock 3	-20	+20
28	RØ1	Register Clock 1	-20	+20
29	RØ2	Register Clock 2	-20	+20
30	SS	Substrate	0	
31	SØ3	Store Clock 3	-20	+20
32	SØ1	Store Clock 1	-20	+20
33	IØ1	Image Clock 1	-20	+20
34	IØ2	Image Clock 2	-20	+20
35	SS	Substrate	0	
36	IG	Isolation Gate	-20	+20

NOTES

11. Anti-blooming is not available on this device type. However, ABD is used for connection purposes and must be biased as specified.

12. Permanent damage may result if, in operation, OSL or OSH experience short-circuit conditions.

Maximum voltages between pairs of pins:

PIN	CONNECTION	PIN	CONNECTION	MIN (V)	MAX (V)
15	OSH	11	ODH	-15	+15
16	OSL	13	ODL	-15	+15
19	RØ2HV	18	RØDC	-20	+50
19	RØ2HV	27	RØ3	-20	+50
Output transistor current (mA)					20

OPERATING CONDITIONS

Typical operating voltages are as given in the table below. Some adjustment within the minimum-maximum range specified may be required to optimise performance.

CONNECTION	PULSE AMPLITUDE OR DC LEVEL (V)		
	Min	Typical	Max
IØ1,2,3,4 high	+5 (see note 13)	+7	+9 (see note 13)
IØ1,2,3,4 low	-6	-5	-4
SØ1,2,3,4 high	+5 (see note 13)	+7	+9 (see note 13)
SØ1,2,3,4 low	-6	-5	-4
RØ1,2,3 high	+8	+12	+13
RØ1,2,3 low	-	0	-
RØ2HV high	+20	+40	+50 (see note 4)
RØ2HV low	0	+4	+5
ØR high	see note 14	+10	see note 14
ØR low	-	0	-
RØDC	+2	+3	+5
OG	+1	+3	+5
IG	-	-5	-
SS	0	+4.5	+7
ODL, ODH	+25	+28	+32
RD	+15	+17	+20
ABD	+10	+18	+20
DG low	-	0	-
DG high	+10	+12	+13
DD	+20	+24	+25

NOTES

- IØ and SØ adjustment may be common.
- ØR high level may be adjusted in common with RØ1,2,3.
- Between the two amplifiers, common connections are made to the reset gates (ØR), reset drains (RD) and output gates (OG).
- An external load is required for each output amplifier. For the HR amplifier, this can be a resistor of about 5 kΩ (non-critical) or a constant current type of about 5 mA. For the LS amplifier, the load should be either 3.3 kΩ or 7.5 mA. The on-chip amplifier power dissipation is approximately 30 mW for the HR amplifier and 50 mW for the LS amplifier.

DRIVE PULSE WAVEFORM SPECIFICATION

The device is of a 4-phase construction, designed to operate in 2-phase inverted mode. This is achieved by applying common timings to phases $\emptyset 1$ and $\emptyset 2$, and phases $\emptyset 3$ and $\emptyset 4$ of the image and store sections. Suggested timing diagrams are shown in Figs. 4 - 11. The following are suggested pulse rise and fall times.

CLOCK PULSE	TYPICAL RISE TIME τ (ns)	TYPICAL FALL TIME τ (ns)	TYPICAL PULSE OVERLAP
I \emptyset	140 < τ < 200	140 < τ < 200	@90% points
S \emptyset	140 < τ < 200	140 < τ < 200	@90% points
R $\emptyset 1$	10	10	@70% points
R $\emptyset 2$	10	10	@70% points
R $\emptyset 3$	10	10	@70% points
R $\emptyset 2HV$	25	25	see note 18
R $\emptyset 2HV$	Sine	Sine	Sinusoid- high on falling edge of R $\emptyset 1$

NOTES

17. Register clock pulses are as shown in Figs. 5 and 6.
18. An example clocking scheme is shown in Fig. 5. R $\emptyset 2HV$ can also be operated with a normal clock pulse, as shown in Fig. 6. The requirement for successful clocking is that R $\emptyset 2HV$ reaches its maximum amplitude before R $\emptyset 1$ goes low.

ELECTRICAL INTERFACE CHARACTERISTICS

ELECTRODE CAPACITANCES AT MID CLOCK LEVELS				
Connection	Capacitance to SS	Inter-phase Capacitances	Total Capacitance	Units
I $\emptyset 1$	2.4	2.4	7.2	nF
I $\emptyset 2$	5.4	2.4	10.2	nF
I $\emptyset 3$	2.4	2.4	7.2	nF
I $\emptyset 4$	5.4	2.4	10.2	nF
S $\emptyset 1$	2.4	2.4	7.2	nF
S $\emptyset 2$	5.4	2.4	10.2	nF
S $\emptyset 3$	2.4	2.4	7.2	nF
S $\emptyset 4$	5.4	2.4	10.2	nF
R $\emptyset 1$	68	98	166	pF
R $\emptyset 2$	56	68	124	pF
R $\emptyset 3$	89	74	163	pF
R $\emptyset 2HV$	15	18	33	pF
SERIES RESISTANCES				
Connection	Approximate Total Series Resistance			
I $\emptyset 1$	16			Ω
I $\emptyset 2$	14			Ω
I $\emptyset 3$	16			Ω
I $\emptyset 4$	14			Ω
S $\emptyset 1$	16			Ω
S $\emptyset 2$	14			Ω
S $\emptyset 3$	16			Ω
S $\emptyset 4$	14			Ω
R $\emptyset 1$	6			Ω
R $\emptyset 2$	6			Ω
R $\emptyset 3$	6			Ω
R $\emptyset 2HV$	8			Ω
APPROXIMATE OUTPUT IMPEDANCE				
Large Signal Amplifier	350			Ω
High Responsivity Amplifier	400			Ω

PULSE TIMINGS AND OVERLAPS

Figure 4: CLOCKING SCHEME FOR 2-PHASE INVERTED MODE OPERATION

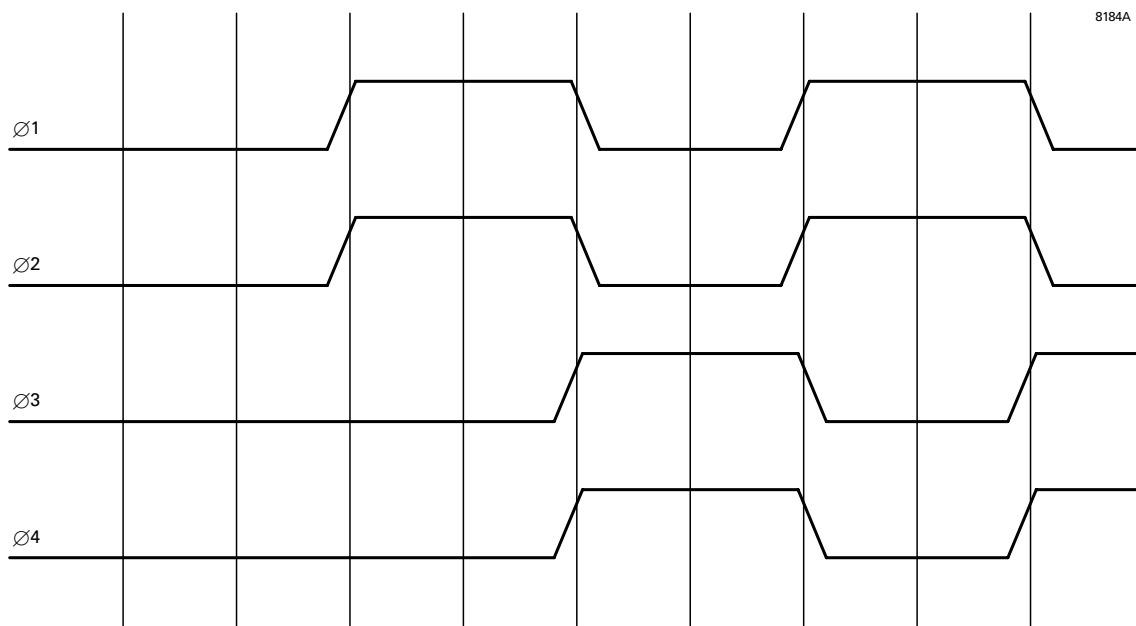


Figure 5: CLOCKING SCHEME FOR MULTIPLICATION GAIN
(Sine wave clocking scheme) (see note 19)

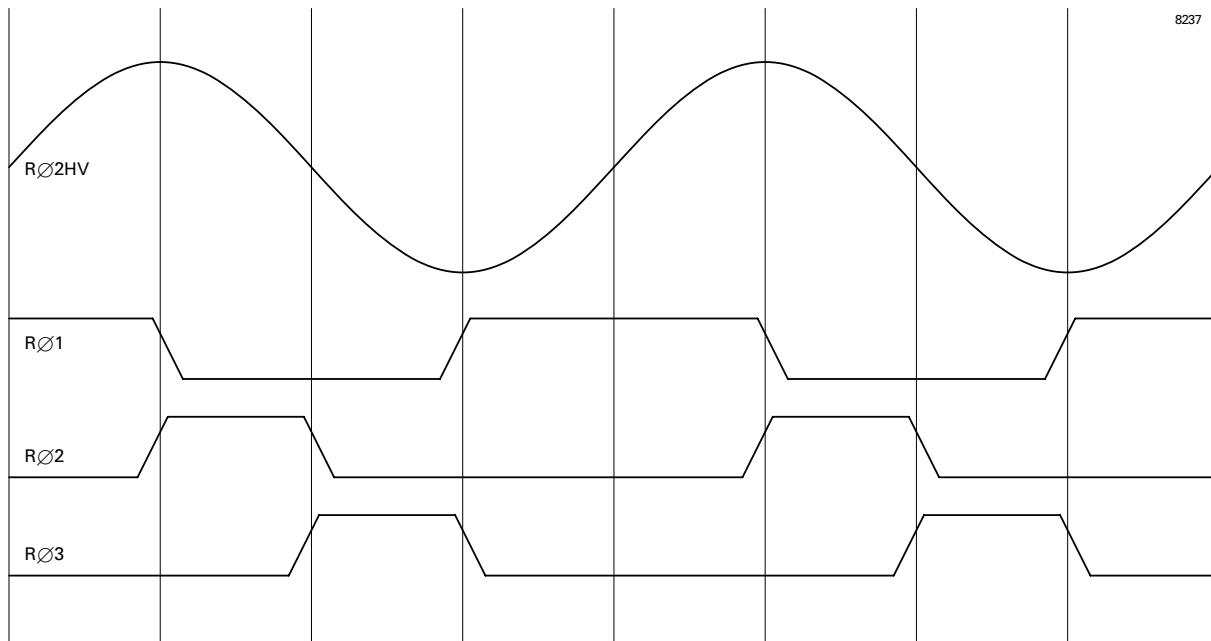
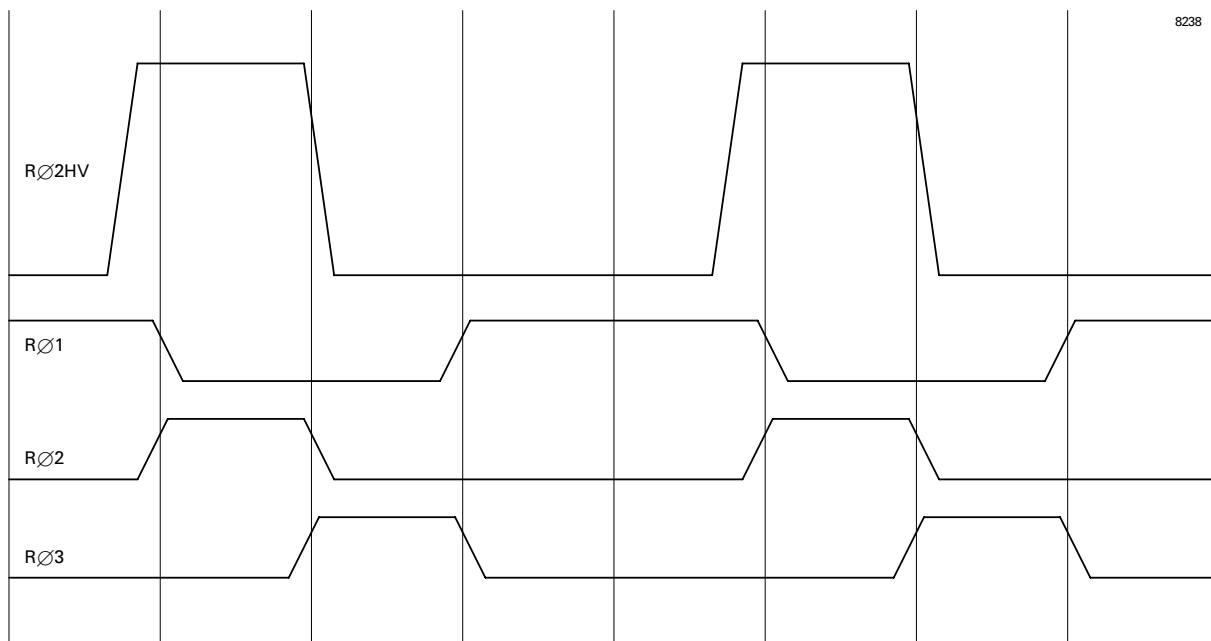


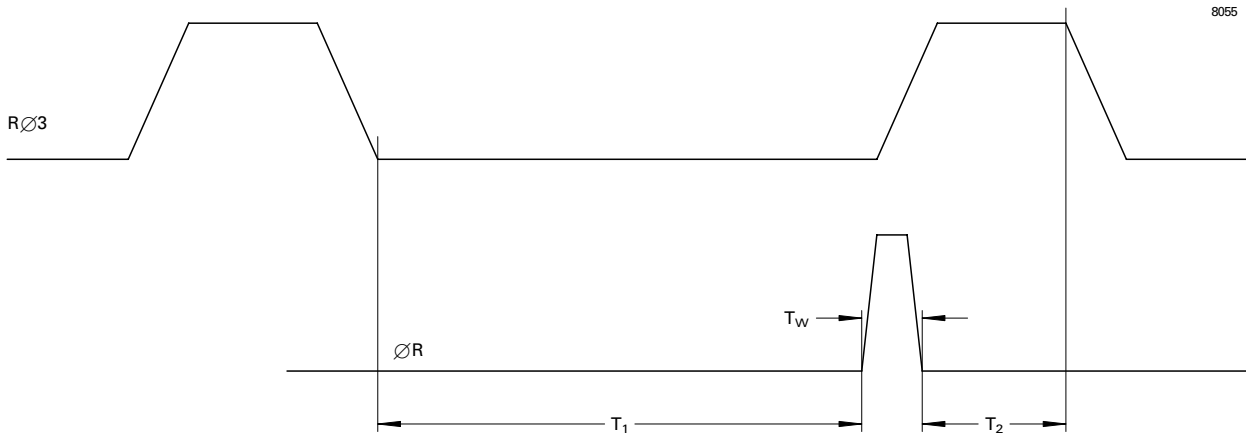
Figure 6: CLOCKING SCHEME FOR MULTIPLICATION GAIN
(Conventional clocking scheme) (see note 19)



NOTE

19. To operate through the OSH output amplifier, the RØ1 and RØ2 waveforms should be interchanged.

Figure 7: RESET PULSE



$T_W = 10 \text{ ns typical}$
 $T_1 = \text{output valid}$
 $T_2 > 0 \text{ ns}$

Figure 8: PULSE AND OUTPUT TIMING

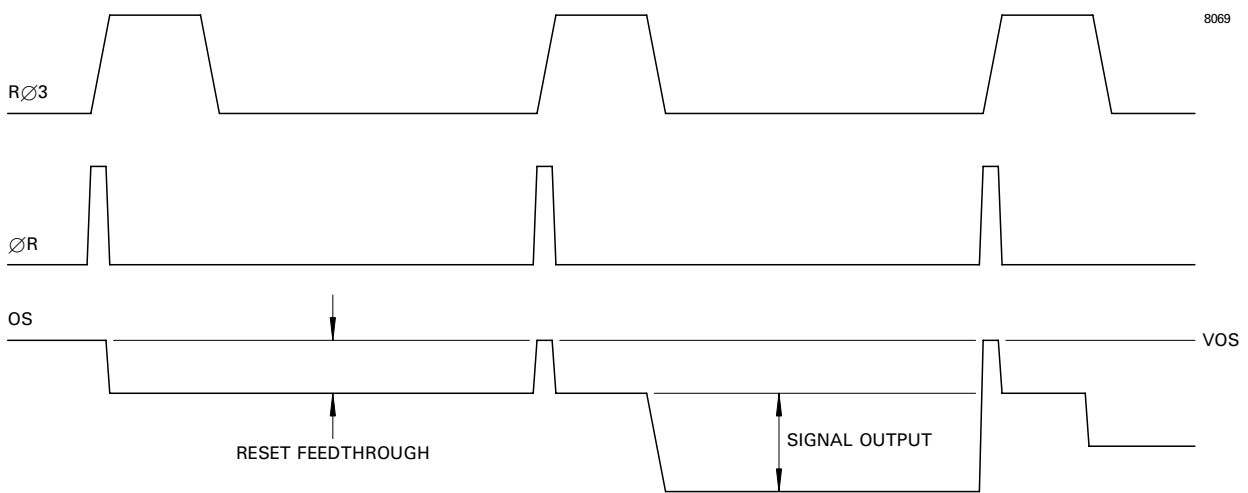


Figure 9: EXAMPLE FRAME TIMING DIAGRAM

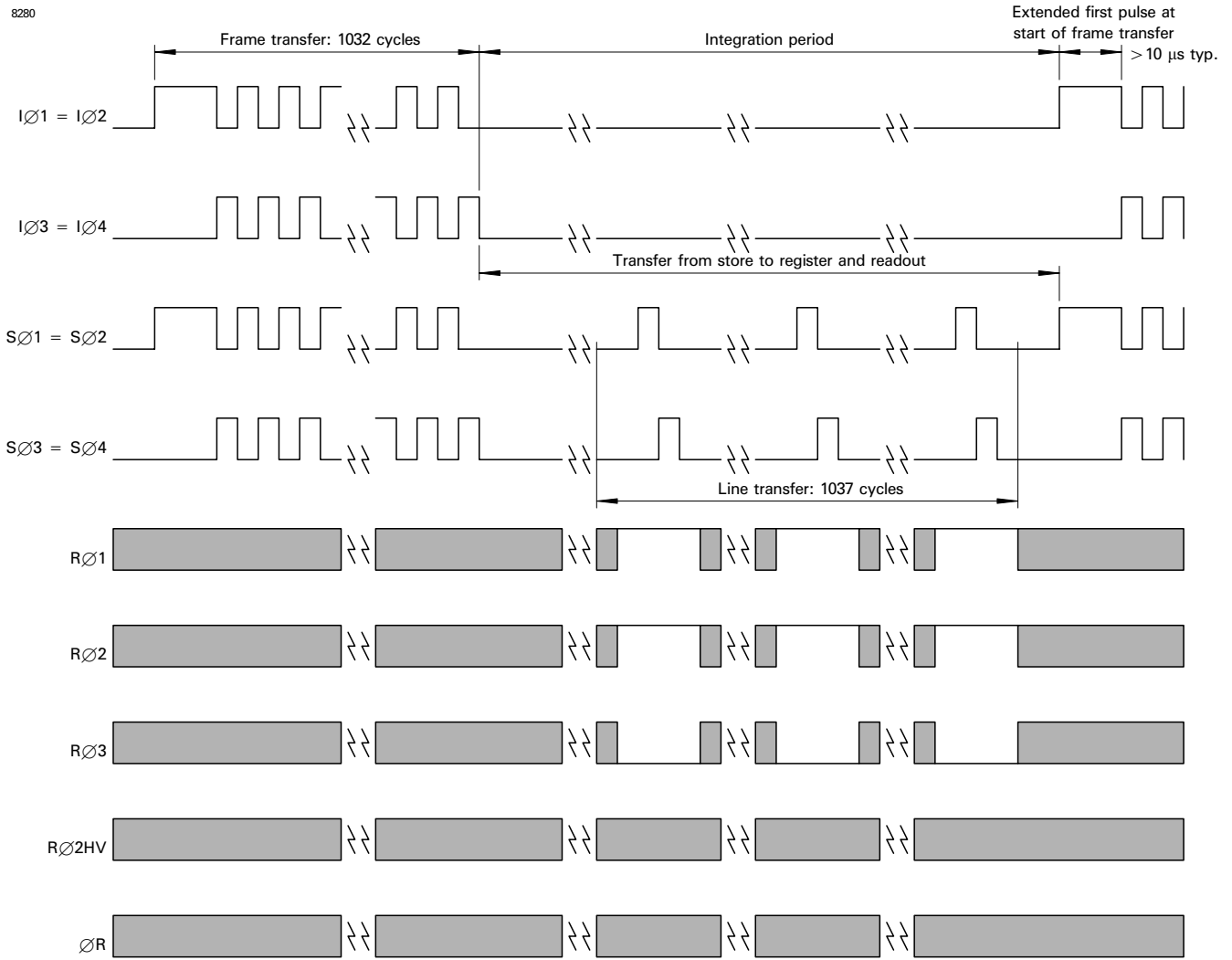


Figure 10: EXAMPLE LINE TIMING DIAGRAM (Operation through OSL, see notes 19 and 22)

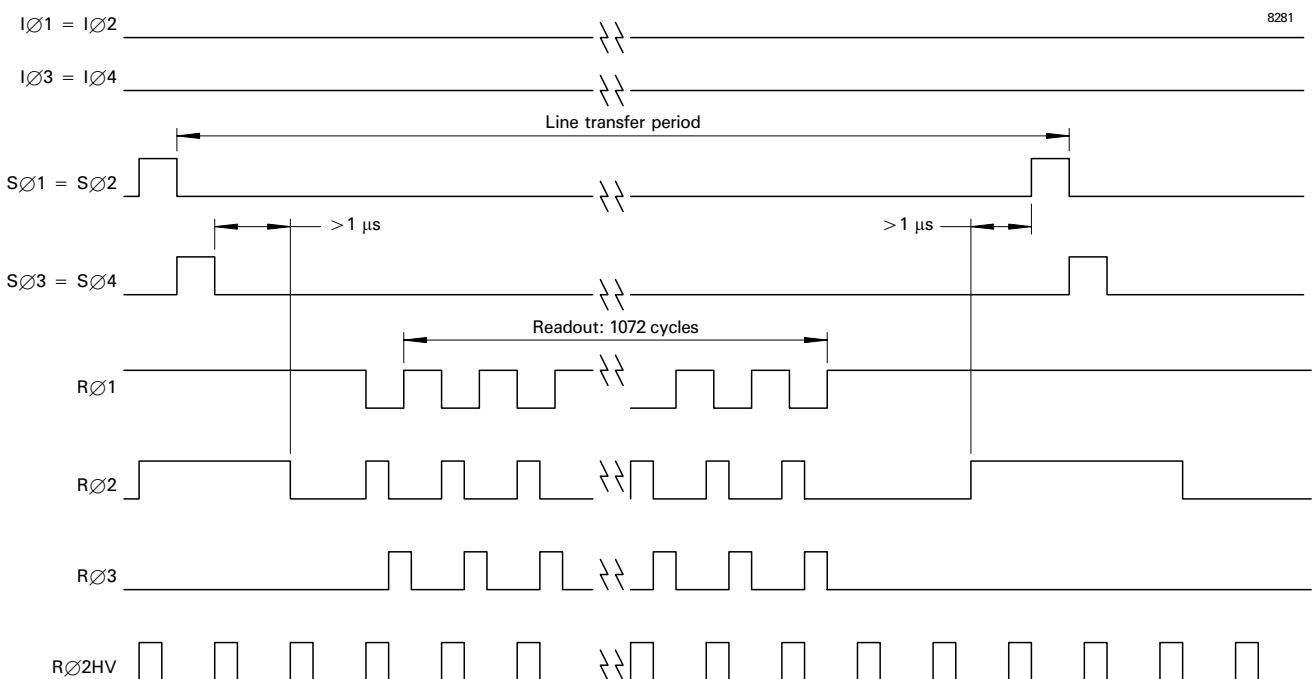
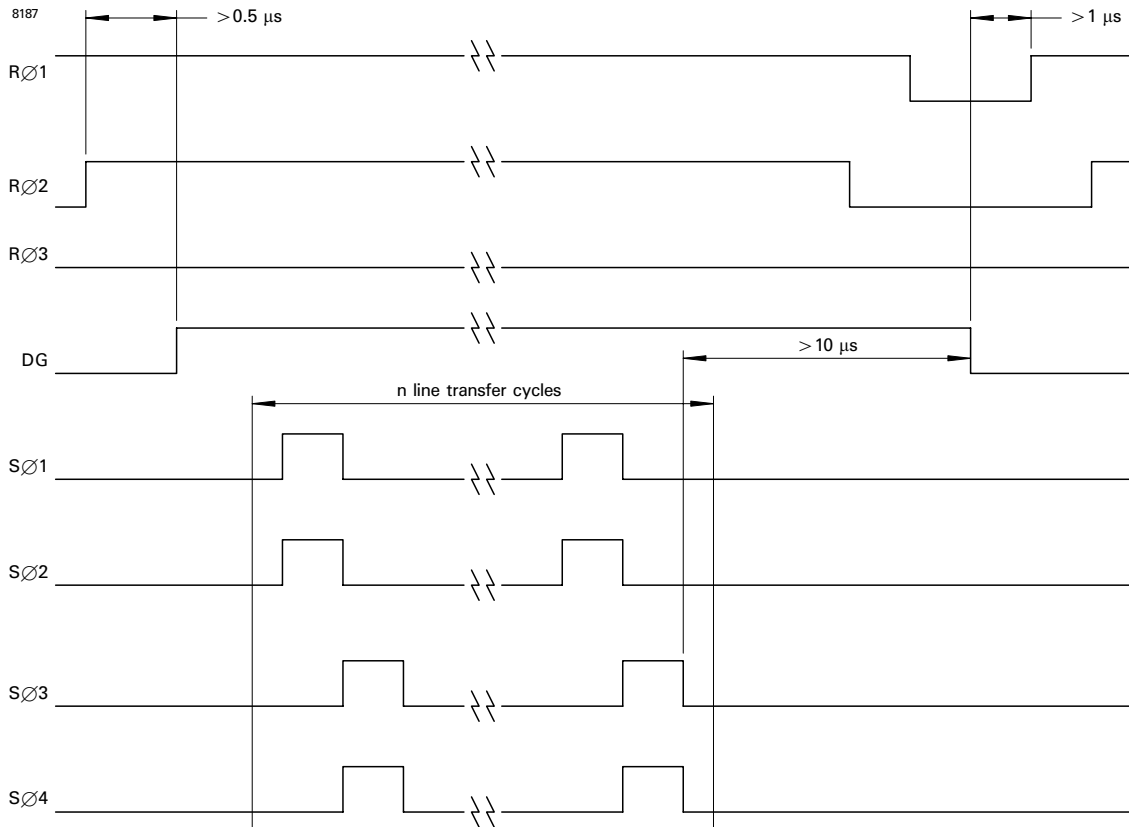


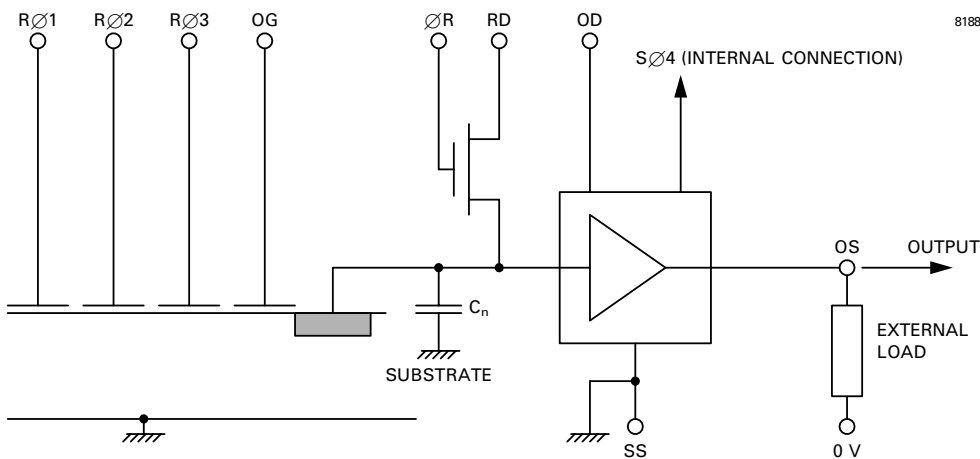
Figure 11: OPERATION OF THE DUMP GATE TO DUMP n LINES OF UNWANTED DATA FROM THE STANDARD REGISTER



NOTE

20. Wanted lines of data must be completely read out before dumping unwanted data.

Figure 12: OUTPUT CIRCUIT SCHEMATIC (OSL and OSH Amplifiers)



NOTE

21. The amplifiers have a DC restoration circuit that is internally activated whenever SØ4 is high.

Figure 13: SCHEMATIC CHIP DIAGRAM

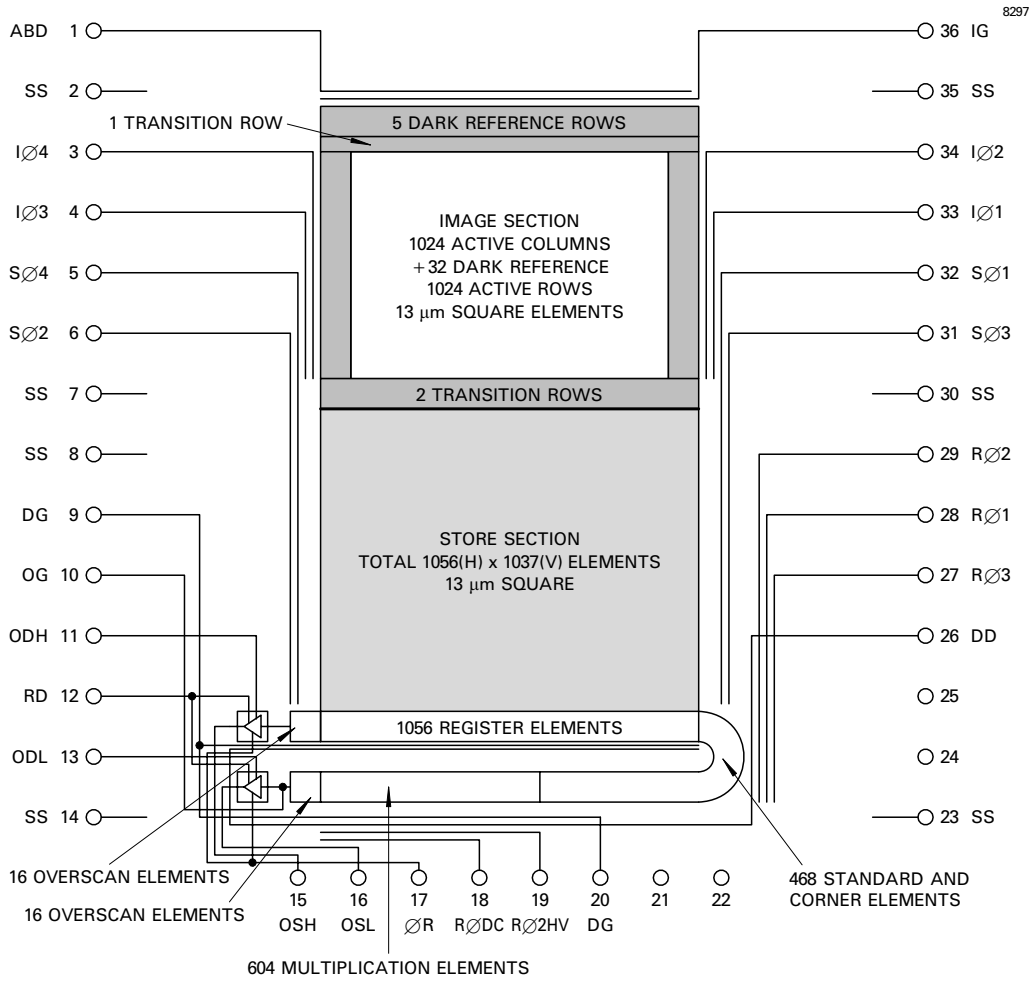
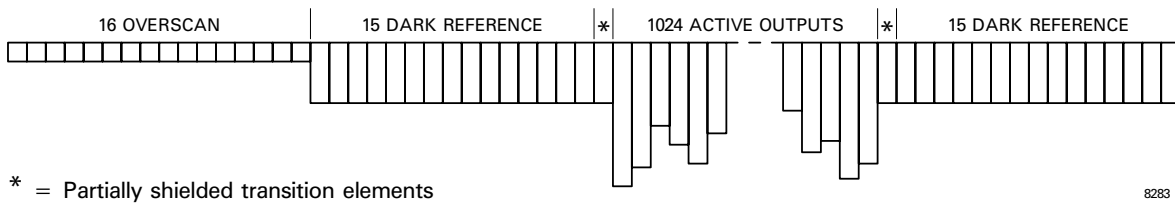


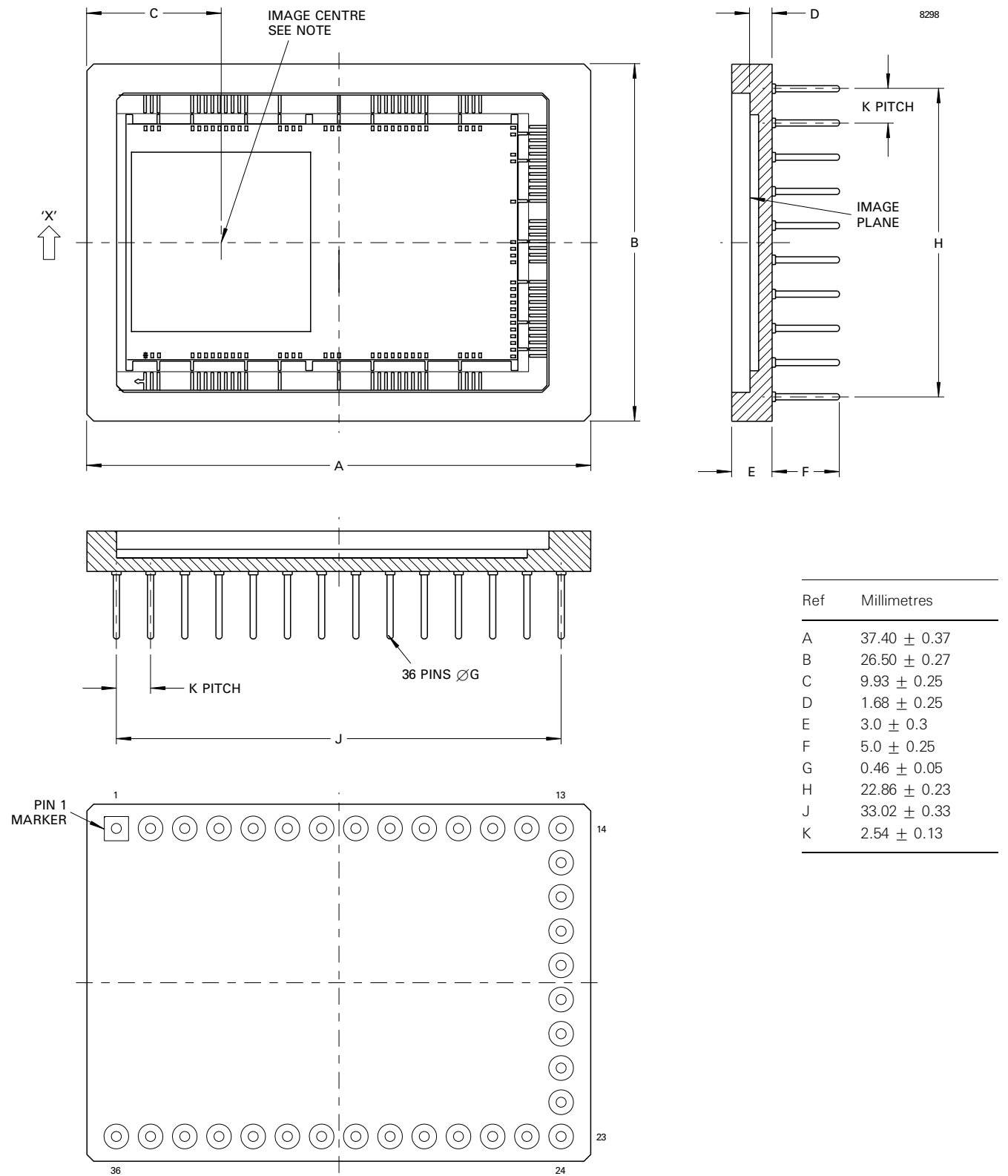
Figure 14: LINE OUTPUT FORMAT (for Example Line Timing Figure 10)



NOTE

22. There is a 1-line propagation delay between transferring a line from the store section to the standard register and reading it out through the OSL output amplifier.

Figure 15: PACKAGE OUTLINE



Outline Note

The image centre is aligned centrally in the package in direction 'X', to within a tolerance of ± 0.2 mm.

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