

**FEATURES**

- 1024 by 1024 1:1 Image Format
- Image Area 13.3 x 13.3 mm
- Back Illuminated Format
- Frame Transfer Operation
- 13  $\mu\text{m}$  Square Pixels
- Symmetrical Anti-static Gate Protection
- Very Low Noise Output Amplifiers
- Gated Dump Drain on Output Register
- 100% Active Area
- Advanced Inverted Mode Operation (AIMO)

**APPLICATIONS**

- Spectroscopy
- Scientific Imaging
- Star Tracking
- Medical Imaging

**INTRODUCTION**

This version of the CCD47 family of sensors has full-frame architecture. Back illumination technology, in combination with extremely low noise amplifiers, makes the device well suited to the most demanding scientific applications. To improve the sensitivity further, the CCD is manufactured without anti-blooming structures.

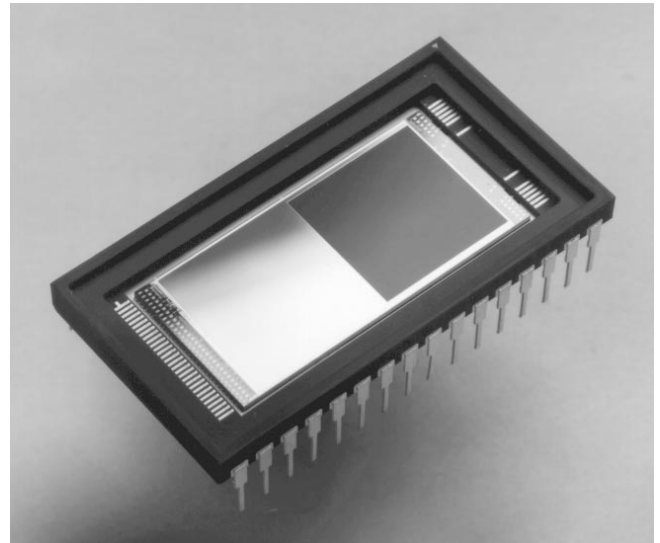
This device has a single serial output register. Separate charge detection circuits are incorporated at each end of the register, which is split so that a line of charge can be transferred to either output, or split between the two.

The register is provided with a drain and control gate along the outer edge of the channel for charge dump purposes.

The sensor is made using Marconi Applied Technologies' Advanced Inverted Mode process to minimise dark current, allowing the device to be operated with extended integration periods and minimal cooling.

Other variants of the CCD47-20 available are front illuminated format and non-inverted mode. In common with all Marconi Applied Technologies CCD Sensors, the CCD47-20 is also available with a fibre-optic window or taper, or with a phosphor coating.

Designers are advised to consult Marconi Applied Technologies should they be considering using CCD sensors in abnormal environments or if they require customised packaging.



**TYPICAL PERFORMANCE**

Maximum readout frequency . . . . .	5	MHz
Output responsivity . . . . .	4.5	$\mu\text{V}/\text{e}^-$
Peak signal . . . . .	100	$\text{ke}^-/\text{pixel}$
Dynamic range (at 20 kHz) . . . . .	~50 000:1	
Spectral range . . . . .	200 - 1100	nm
Readout noise (at 20 kHz) . . . . .	2.0	$\text{e}^- \text{ rms}$

**GENERAL DATA**

**Format**

Image area . . . . .	13.3 x 13.3	mm
Active pixels (H) . . . . .	1024	
(V) . . . . .	1024	
Pixel size . . . . .	13 x 13	$\mu\text{m}$
Storage area . . . . .	13.3 x 13.3	mm
Pixels (H) . . . . .	1024	
(V) . . . . .	1033	

Additional pixels are provided in the image area for dark reference and over-scanning purposes.

Number of output amplifiers . . . . .	2	
Weight (approx, no window) . . . . .	7.5	g

**Package**

Package size . . . . .	22.7 x 42.0	mm
Number of pins . . . . .	32	
Inter-pin spacing . . . . .	2.54	mm
Window material . . . . .	quartz or removable glass	
Type . . . . .	ceramic DIL array	

## PERFORMANCE

	Min	Typical	Max	
Peak charge storage (see note 1)	60k	100k	-	e <sup>-</sup> /pixel
Peak output voltage (no binning)	-	450	-	mV
Dark signal at 293 K (see notes 2 and 3)	-	250	500	e <sup>-</sup> /pixel/s
Dynamic range (see note 4)	-	60 000	-	
Charge transfer efficiency (see note 5):				
parallel	-	99.9999	-	%
serial	-	99.9993	-	%
Output amplifier responsivity (see note 3)	3.0	4.5	6.0	μV/e <sup>-</sup>
Readout noise at 253 K (see notes 3 and 6)	-	2.0	4.0	rms e <sup>-</sup> /pixel
Maximum readout frequency (see note 7)	-	5.0	-	MHz
Dark signal non-uniformity (std. deviation) (see notes 3 and 8)	-	60	125	e <sup>-</sup> /pixel/s

### Spectral Response (at 253 K)

Wavelength (nm)	Minimum Response (QE)				Response Non-uniformity (1σ)	
	UV Coated	Midband Coated	Broadband Coated	Uncoated		
300	45	not specified	not specified	not specified	-	%
350	45	15	25	10	5	%
400	55	40	55	25	3	%
500	60	85	75	55	3	%
650	60	85	75	50	3	%
900	30	30	30	30	5	%

## ELECTRICAL INTERFACE CHARACTERISTICS

### Electrode capacitances (measured at mid-clock level)

	Min	Typical	Max	
SØ/SØ interphase	-	3.5	-	nF
IØ/IØ interphase	-	3.5	-	nF
IØ/SS and SØ/SS	-	4.5	-	nF
RØ/RØ interphase	-	40	-	pF
RØ/(SS + DG + OD)	-	60	-	pF
ØR/SS	-	10	-	pF
Output impedance (at typ. operating condition)	-	300	-	Ω

## NOTES

- Signal level at which resolution begins to degrade.
- Measured between 253 and 293 K and V<sub>SS</sub> +9.5 V. Dark signal at any temperature T (kelvin) may be estimated from:  

$$Q_d/Q_{d0} = 1.14 \times 10^6 T^3 e^{-9080/T}$$
 where Q<sub>d0</sub> is the dark signal at T = 293 K (20 °C).
- Test carried out at Marconi Applied Technologies on all sensors.
- Dynamic range is the ratio of full-well capacity to readout noise measured at 253 K and 20 kHz readout speed.
- CCD characterisation measurements made using charge generated by X-ray photons of known energy.
- Measured using a dual-slope integrator technique (i.e. correlated double sampling) with a 20 μs integration period.
- Readout at speeds in excess of 5 MHz into a 15 pF load can be achieved but performance to the parameters given cannot be guaranteed.
- Measured between 253 and 293 K, excluding white defects.

## BLEMISH SPECIFICATION

**Traps** Pixels where charge is temporarily held. Traps are counted if they have a capacity greater than  $200 e^-$  at 253 K.

**Slipped columns** Are counted if they have an amplitude greater than  $200 e^-$ .

**Black spots** Are counted when they have a signal level of less than 80% of the local mean at a signal level of approximately half full-well.

**White spots** Are counted when they have a generation rate 125 times the specified maximum dark signal generation rate (measured between 253 and 293 K). The typical temperature dependence of white spot defects is different from that of the average dark signal and is given by:

$$Q_d/Q_{d0} = 122T^3e^{-6400/T}$$

**White column** A column which contains at least 21 white defects.

**Black column** A column which contains at least 21 black defects.

GRADE	0	1	2
Column defects: black or slipped	0	2	6
white	0	0	2
Black spots	50	100	200
Traps $> 200 e^-$	2	5	12
White spots	50	80	100

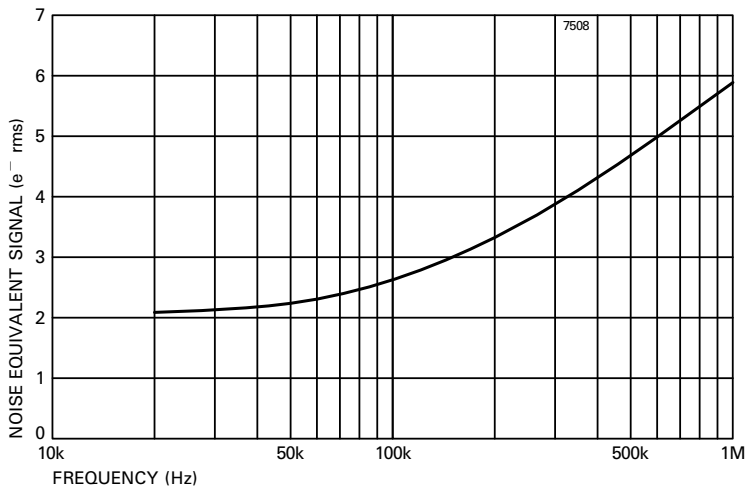
**Grade 5** Devices which are fully functioning, with image quality below that of grade 2, and which may not meet all other performance parameters.

**Note** The effect of temperature on defects is that traps will be observed less at higher temperatures but more may appear below 253 K. The amplitude of white spots and columns will decrease rapidly with temperature.

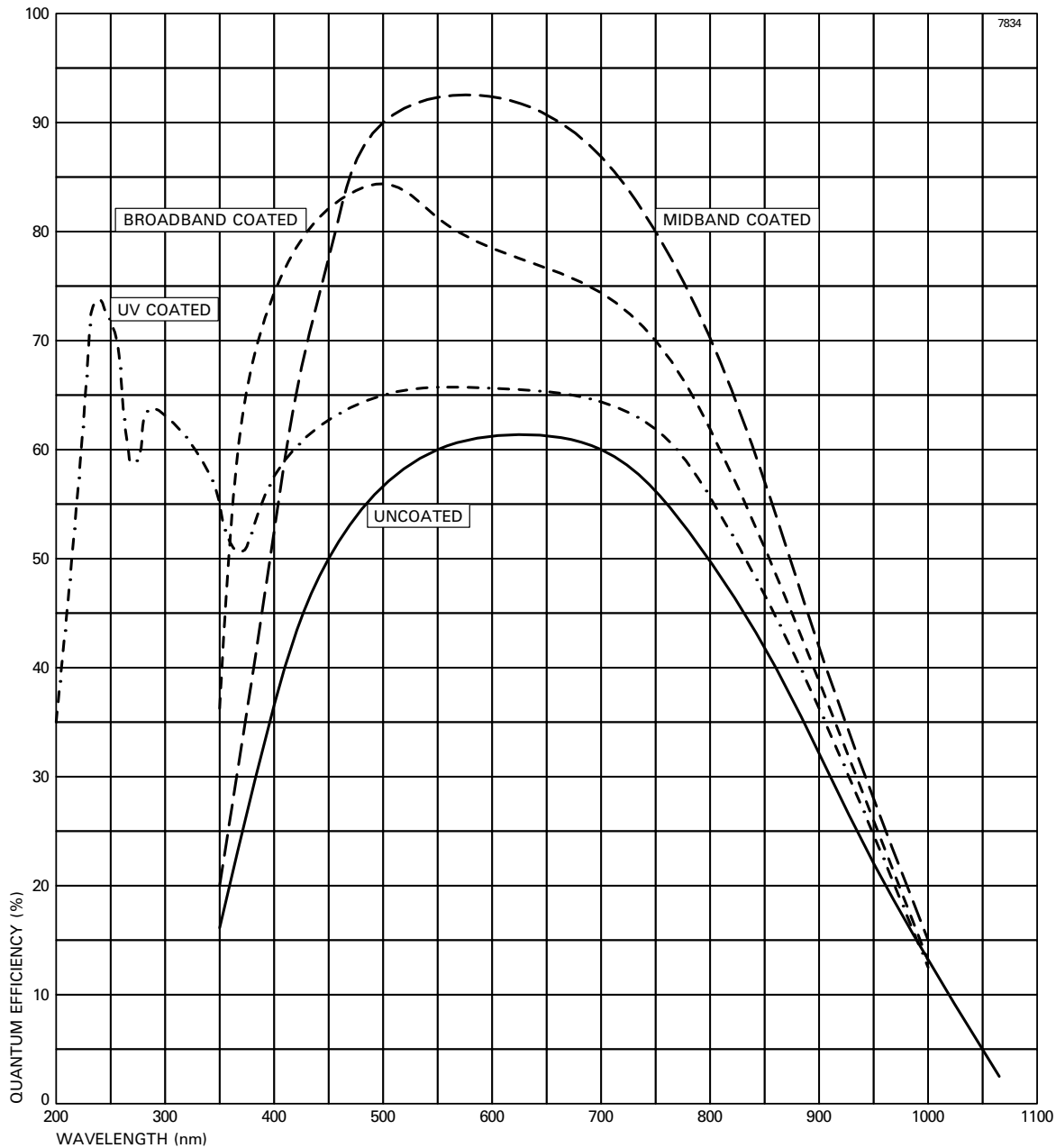
## TYPICAL OUTPUT CIRCUIT NOISE

(Measured using clamp and sample)

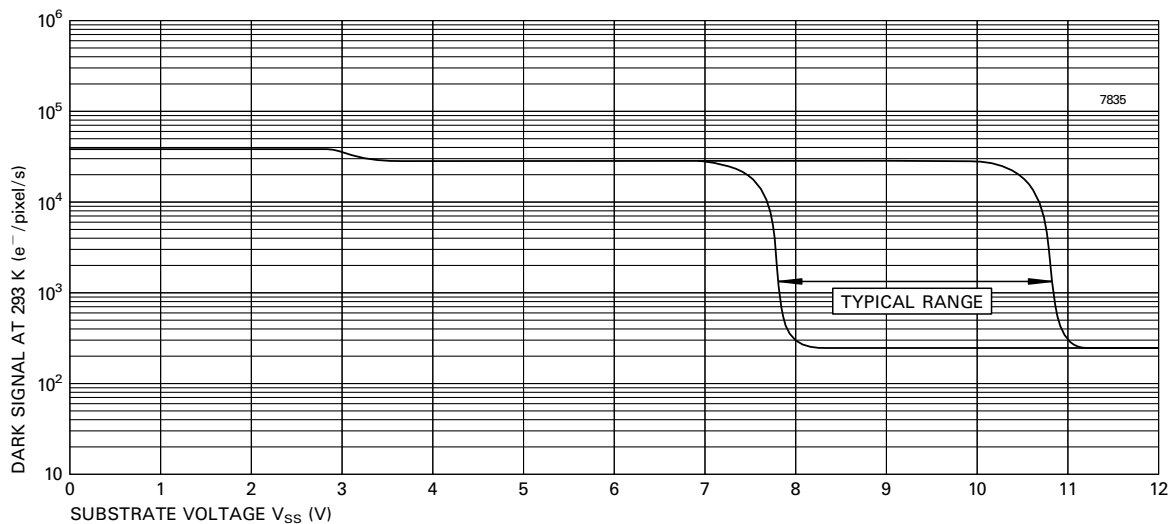
$$V_{SS} = 9.5 \text{ V} \quad V_{RD} = 17 \text{ V} \quad V_{OD} = 29 \text{ V}$$



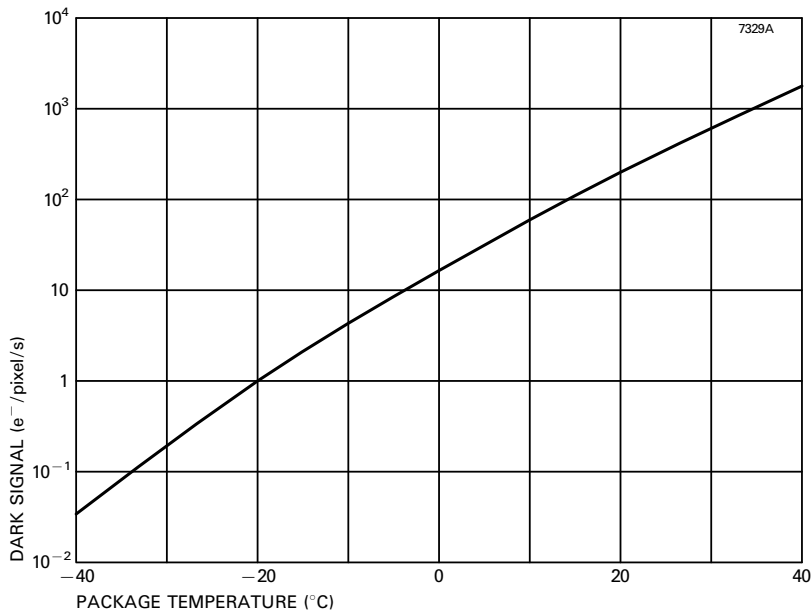
## TYPICAL SPECTRAL RESPONSE (At $-20^{\circ}\text{C}$ , no window)



## TYPICAL VARIATION OF DARK SIGNAL WITH SUBSTRATE VOLTAGE

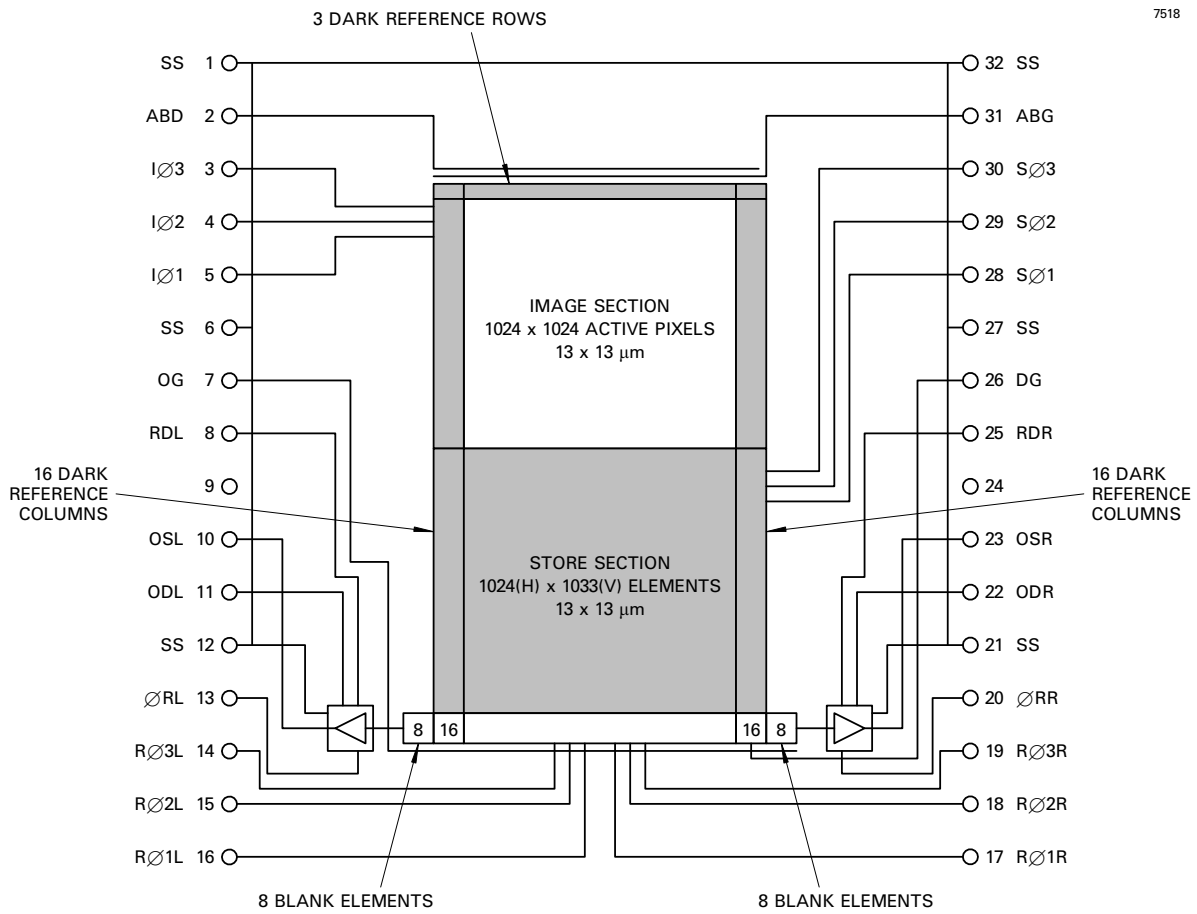


## TYPICAL VARIATION OF DARK SIGNAL WITH TEMPERATURE ( $V_{SS} = +9.5 \text{ V}$ )



## DEVICE SCHEMATIC

7518



## CONNECTIONS, TYPICAL VOLTAGES AND ABSOLUTE MAXIMUM RATINGS

PIN	REF	DESCRIPTION	PULSE AMPLITUDE OR DC LEVEL (V) (See note 9)			MAXIMUM RATINGS with respect to V <sub>SS</sub>
			Min	Typical	Max	
1	SS	Substrate	8	9.5	11	-
2	ABD	Anti-blooming drain (see note 10)	V <sub>OD</sub>			-0.3 to +25 V
3	IØ3	Image area clock	12	15	16	±20 V
4	IØ2	Image area clock	12	15	16	±20 V
5	IØ1	Image area clock	12	15	16	±20 V
6	SS	Substrate	8	9.5	11	-
7	OG	Output gate	1	3	5	±20 V
8	RDL	Reset transistor drain (left amplifier)	15	17	19	-0.3 to +25 V
9	-	No connection	-			-
10	OSL	Output transistor source (left amplifier)	see note 11			-0.3 to +25 V
11	ODL	Output transistor drain (left amplifier)	27	29	32	-0.3 to +35 V
12	SS	Substrate	8	9.5	11	-
13	ØRL	Output reset pulse (left amplifier)	8	12	15	±20 V
14	RØ3L	Output register clock (left section)	8	10	15	±20 V
15	RØ2L	Output register clock (left section)	8	10	15	±20 V
16	RØ1L	Output register clock (left section)	8	10	15	±20 V
17	RØ1R	Output register clock (right section)	8	10	15	±20 V
18	RØ2R	Output register clock (right section)	8	10	15	±20 V
19	RØ3R	Output register clock (right section)	8	10	15	±20 V
20	ØRR	Output reset pulse (right amplifier)	8	12	15	±20 V
21	SS	Substrate	8	9.5	11	-
22	ODR	Output transistor drain (right amplifier)	27	29	32	-0.3 to +35 V
23	OSR	Output transistor source (right amplifier)	see note 11			-0.3 to +25 V
24	-	No connection	-			-
25	RDR	Reset transistor drain (right amplifier)	15	17	19	-0.3 to +25 V
26	DG	Dump gate (see note 12)	-	0	-	±20 V
27	SS	Substrate	8	9.5	11	-
28	SØ1	Storage area clock	12	15	16	±20 V
29	SØ2	Storage area clock	12	15	16	±20 V
30	SØ3	Storage area clock	12	15	16	±20 V
31	ABG	Anti-blooming gate	0	0	5	±20 V
32	SS	Substrate	8	9.5	11	-

Maximum voltages between pairs of pins:

pin 10 (OSL) to pin 11 (ODL) . . . . . ±15 V

pin 22 (ODR) to pin 23 (OSR) . . . . . ±15 V

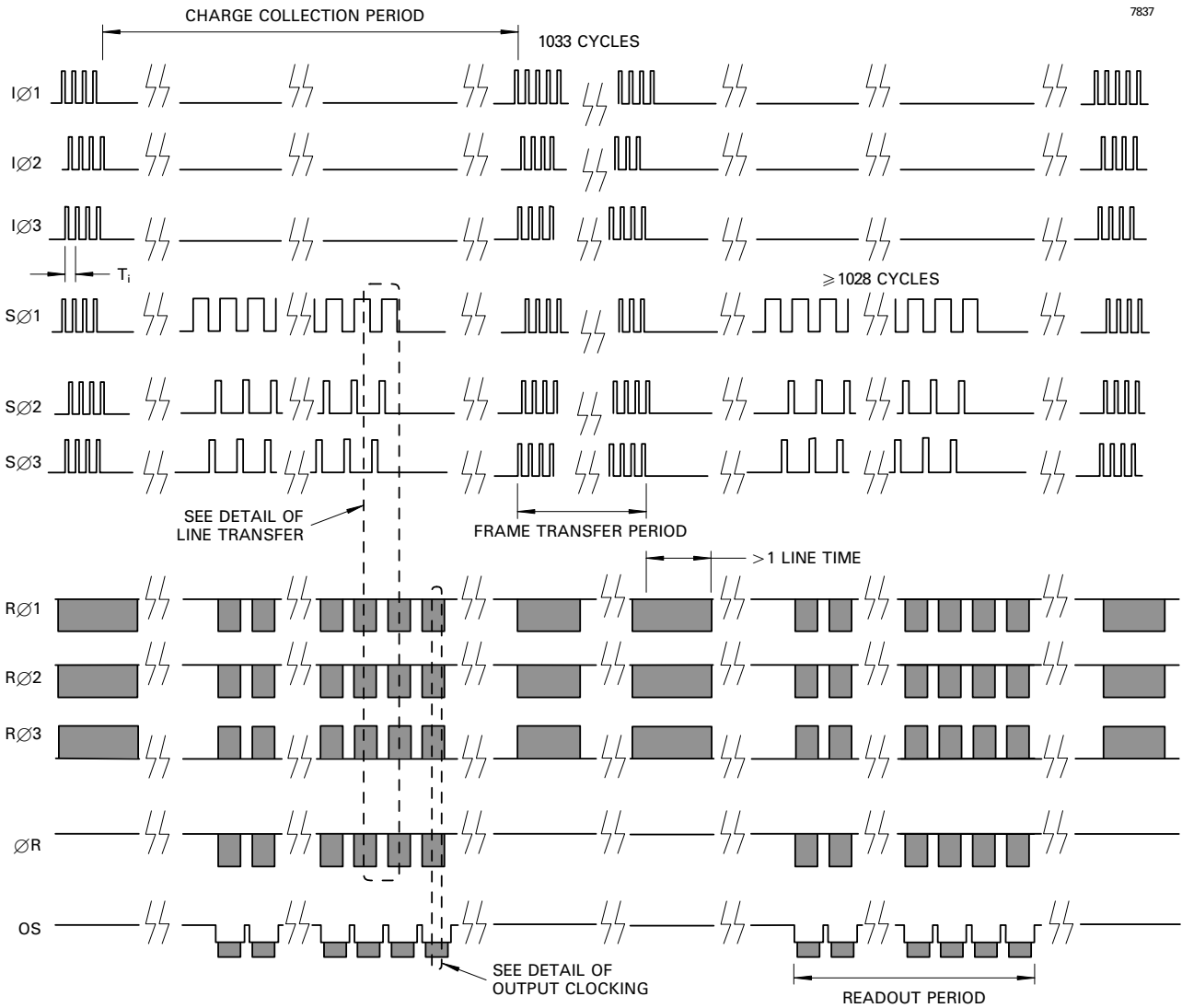
Maximum output transistor current . . . . . 10 mA

### NOTES

9. Readout register clock pulse low levels +1 V; other clock low levels 0 ± 0.5 V.
10. Drain not incorporated, but bias is still necessary.
11. 3 to 5 V below OD. Connect to ground using a 2 to 5 mA current source or appropriate load resistor (typically 5 to 10 kΩ).
12. Non-charge dumping level shown. For operation in charge dumping mode, DG should be pulsed to 12 ± 2 V.
13. All devices will operate at the typical values given. However, some adjustment within the minimum to maximum range may be required to optimise performance for critical applications. It should be noted that conditions for optimum performance may differ from device to device.
14. With the RØ connections shown, the device will operate through the right-hand output only. In order to operate from both outputs RØ1(L) and RØ2(L) should be reversed.

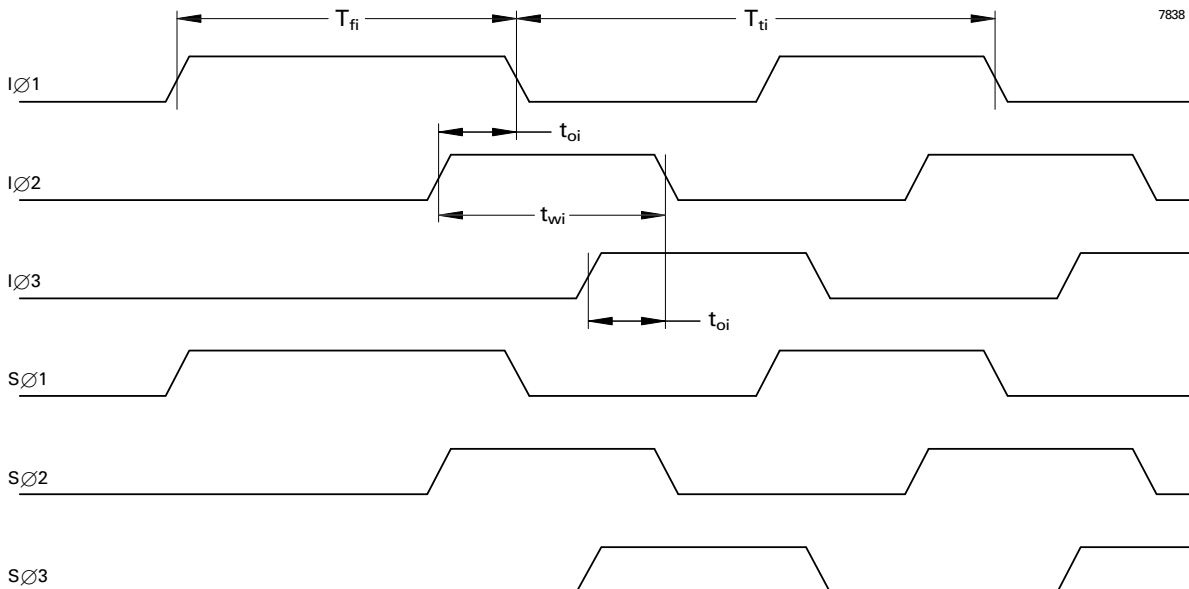
# FRAME TRANSFER TIMING DIAGRAM

7837



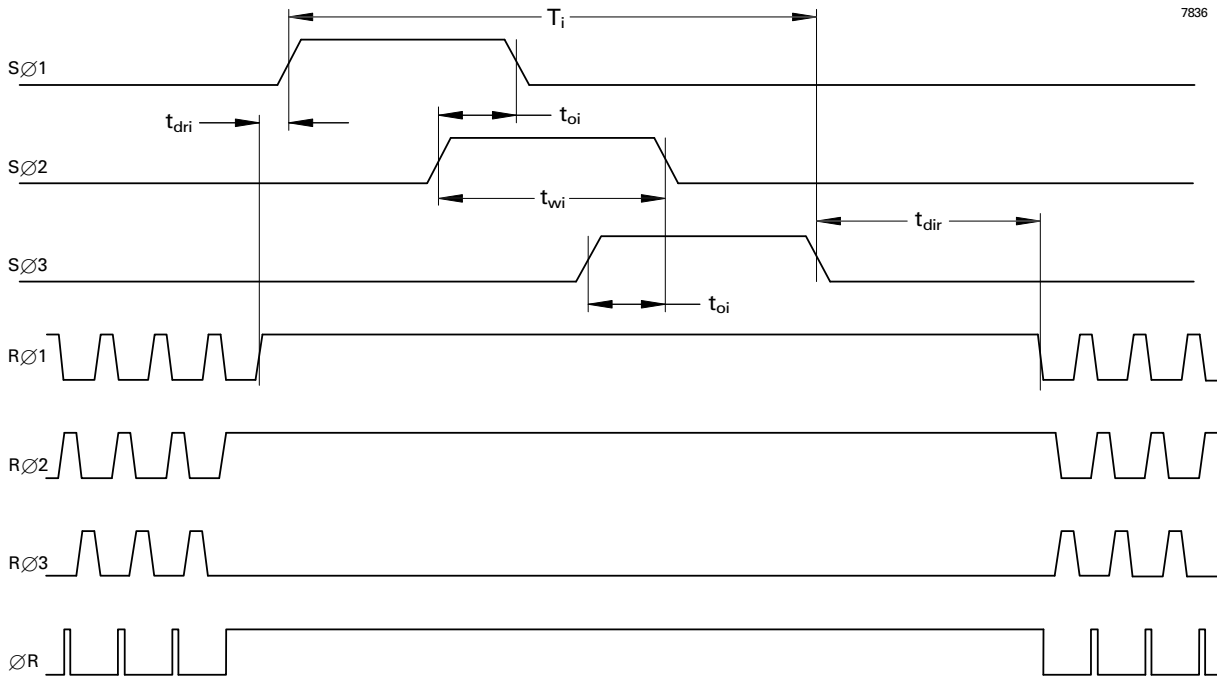
# DETAIL OF FRAME TRANSFER

7838



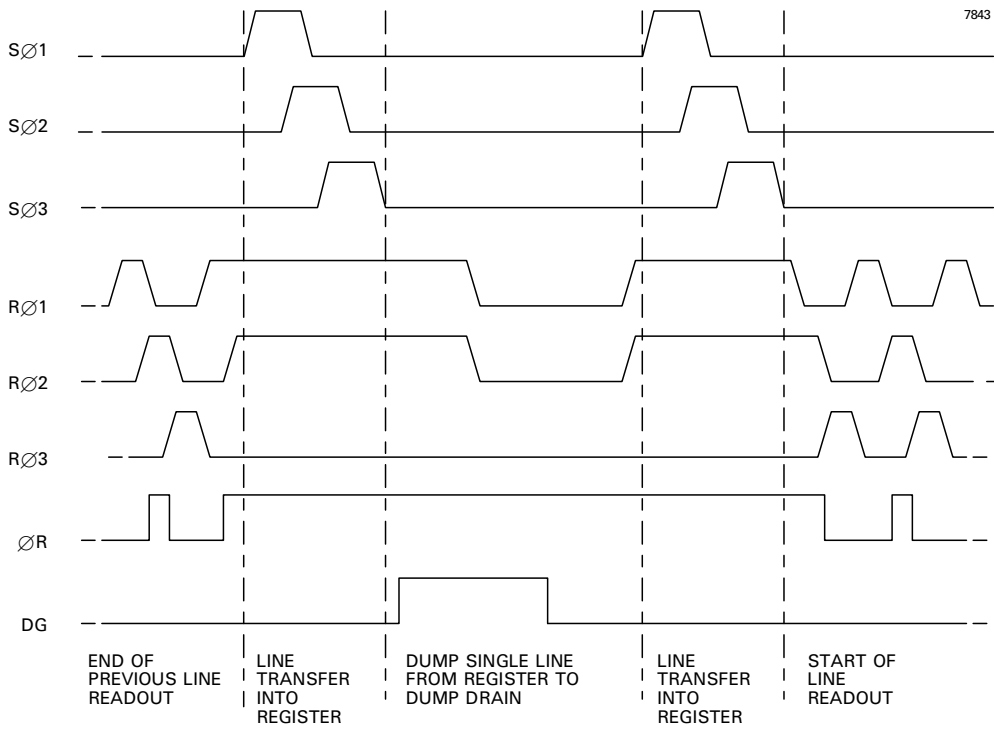
**DETAIL OF LINE TRANSFER**  
 (For output from a single amplifier)

7836

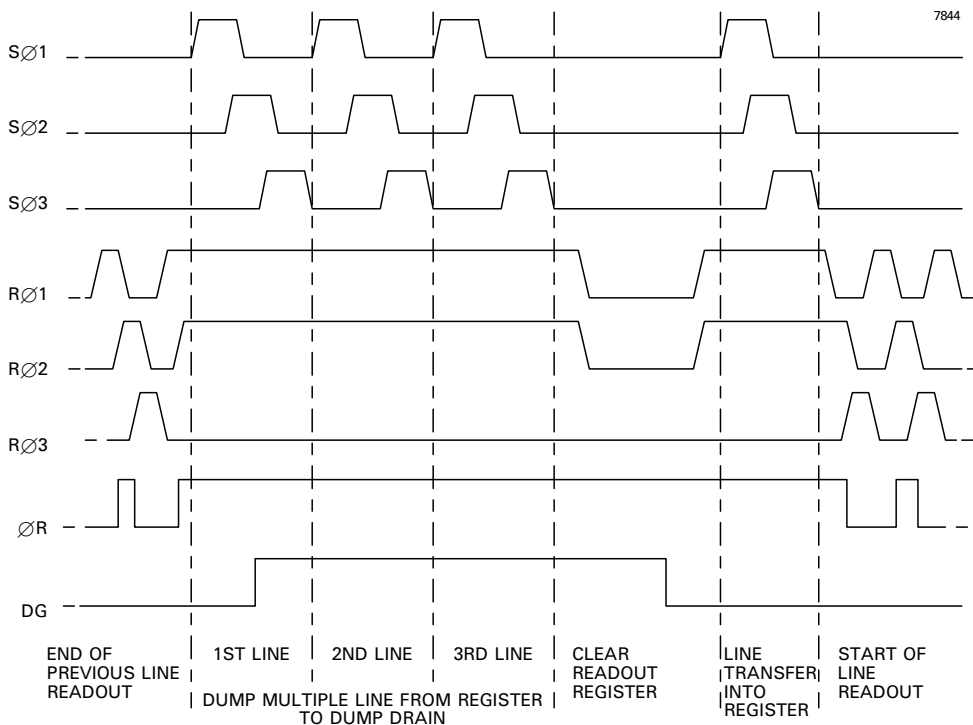




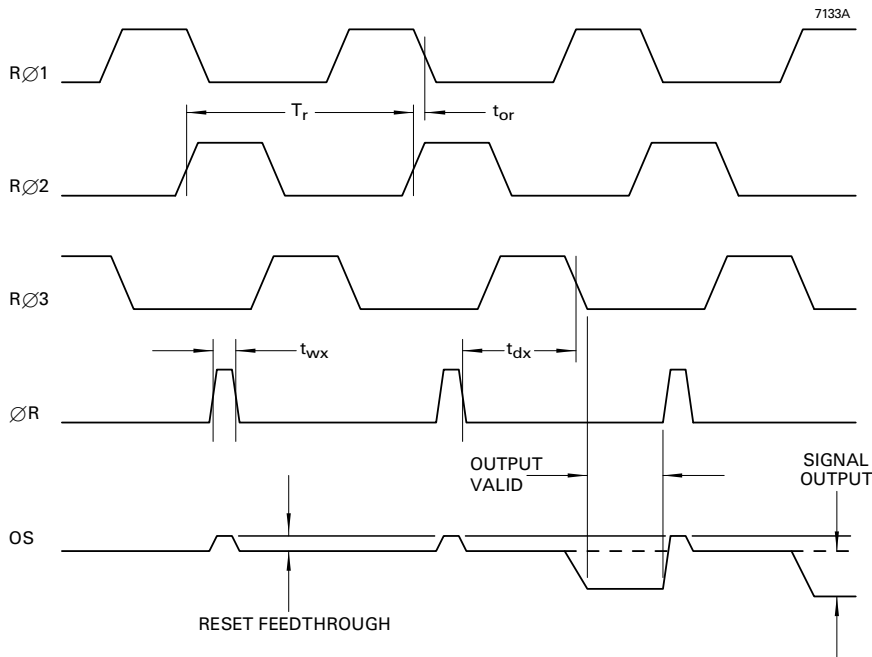
## DETAIL OF VERTICAL LINE TRANSFER (Single line dump)



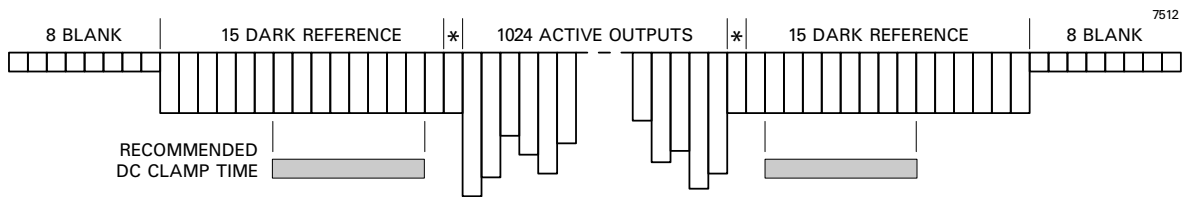
## DETAIL OF VERTICAL LINE TRANSFER (Multiple line dump)



## DETAIL OF OUTPUT CLOCKING



## LINE OUTPUT FORMAT



\* = Partially shielded transition elements

## CLOCK TIMING REQUIREMENTS

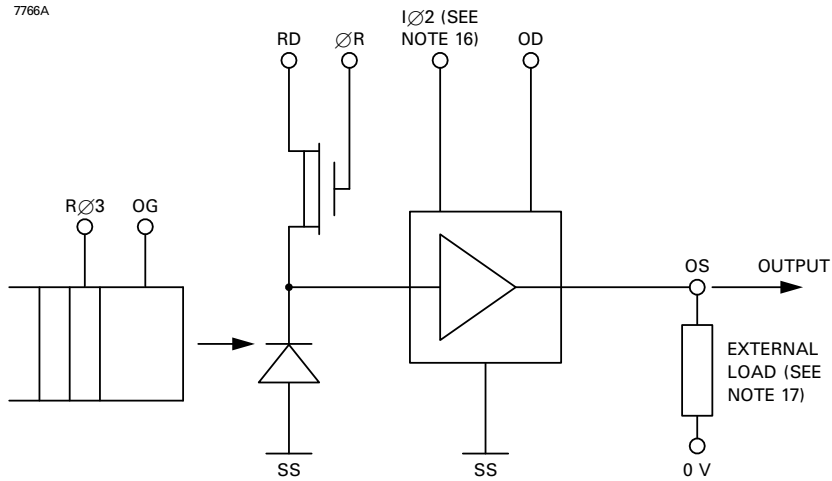
Symbol	Description	Min	Typical	Max	
$T_{fi}$	First frame transfer pulse width	100	150	see note 15	$\mu s$
$T_{ti}$	Frame transfer clock period	7	10	see note 15	$\mu s$
$t_{w_{ti}}$	Frame transfer image clock pulse width	3.5	5	$0.2T_{fi}$	$\mu s$
$T_i$	Store clock period	50	100	see note 15	$\mu s$
$t_{w_i}$	Image/store clock pulse width	25	50	see note 15	$\mu s$
$t_{r_i}$	Image/store clock pulse rise time (10 to 90%)	0.1	5	$0.2T_i$	$\mu s$
$t_{f_i}$	Image/store clock pulse fall time (10 to 90%)	$t_{r_i}$	5	$0.2T_i$	$\mu s$
$t_{o_i}$	Image/store clock pulse overlap	$(t_{r_i} + t_{f_i})/2$	5	$0.2T_i$	$\mu s$
$t_{dir}$	Delay time, SØ stop to RØ start	1	2	see note 15	$\mu s$
$t_{dri}$	Delay time, RØ stop to SØ start	1	1	see note 15	$\mu s$
$T_r$	Output register clock cycle period	200	1000	see note 15	ns
$t_{rr}$	Clock pulse rise time (10 to 90%)	50	$0.1T_r$	$0.3T_r$	ns
$t_{fr}$	Clock pulse fall time (10 to 90%)	$t_{rr}$	$0.1T_r$	$0.3T_r$	ns
$t_{or}$	Clock pulse overlap	20	$0.5t_{rr}$	$0.1T_r$	ns
$t_{wx}$	Reset pulse width	30	$0.1T_r$	$0.3T_r$	ns
$t_{rx}, t_{fx}$	Reset pulse rise and fall times	$0.2t_{wx}$	$0.5t_{rr}$	$0.1T_r$	ns
$t_{dx}$	Delay time, ØR low to RØ3 low	30	$0.5T_r$	$0.8T_r$	ns

## NOTES

15. No maximum other than that necessary to achieve an acceptable dark signal at the longer readout times.

## OUTPUT CIRCUIT

7766A

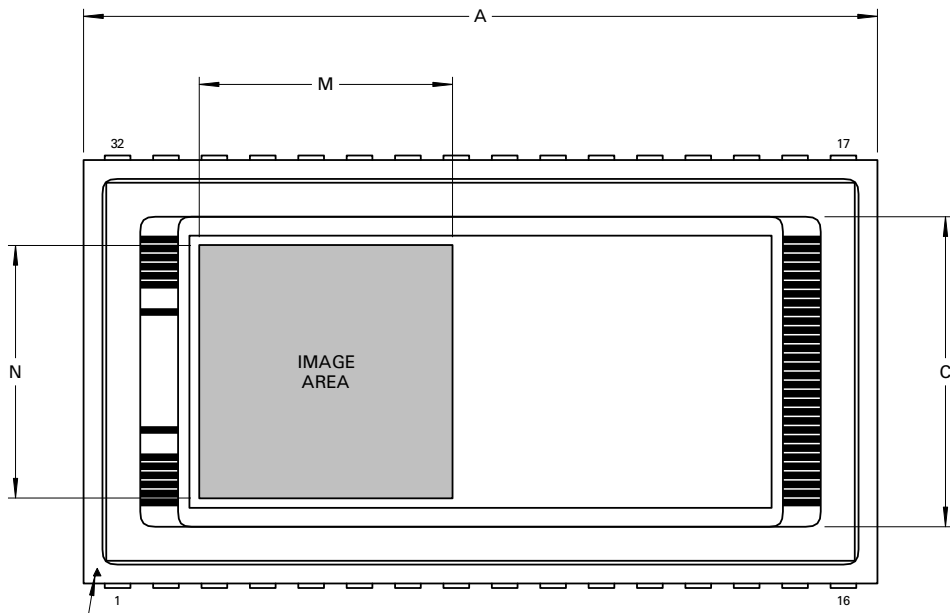


## NOTES

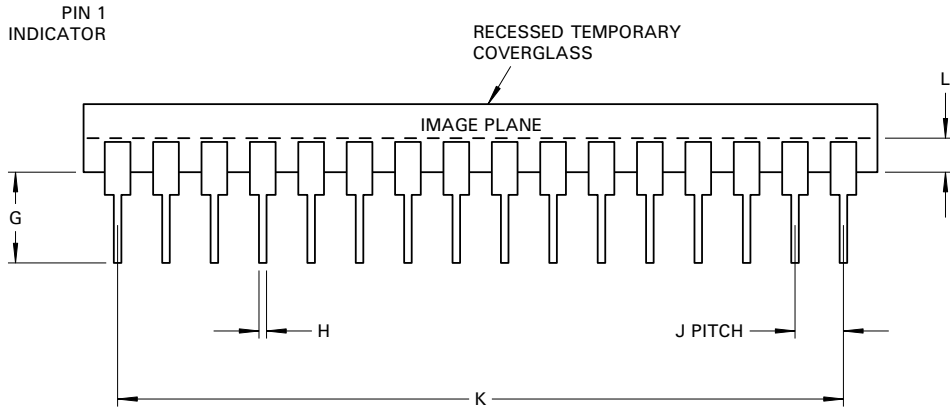
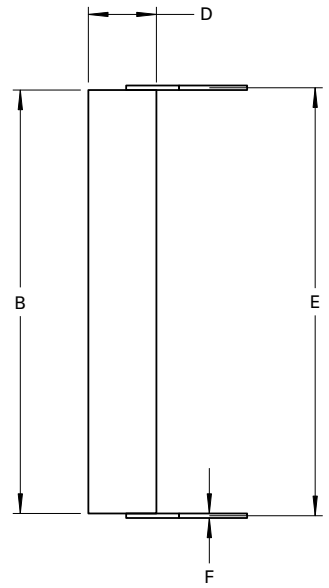
16. The amplifier has a DC restoration circuit which is internally activated whenever IØ2 is high.
17. Not critical; can be a 3 to 5 mA constant current supply or an appropriate load resistor.

# OUTLINE

(All dimensions without limits are nominal)



7522



Ref	Millimetres
A	42.00 ± 0.42
B	22.73 ± 0.26
C	16.60 ± 0.25
D	3.64 ± 0.37
E	22.86 ± 0.25
F	0.254 + 0.051 - 0.025
G	5.0 ± 0.5
H	0.457 ± 0.051
J	2.54 ± 0.13
K	38.1
L	1.65 ± 0.25
M	13.3
N	13.3

## ORDERING INFORMATION

Options include:

- Temporary Quartz Window
- Permanent Quartz Window
- Temporary Glass Window
- Permanent Glass Window
- Fibre-optic Coupling
- UV Coating
- X-ray Phosphor Coating

For further information on the performance of these and other options, please contact Marconi Applied Technologies.

## HANDLING CCD SENSORS

CCD sensors, in common with most high performance MOS IC devices, are static sensitive. In certain cases a discharge of static electricity may destroy or irreversibly degrade the device. Accordingly, full antistatic 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.

Evidence of incorrect handling will invalidate the warranty. All devices are provided with internal protection circuits to the gate electrodes (pins 3, 4, 5, 7, 13, 14, 15, 16, 17, 18, 19, 20, 26, 28, 29, 30, 31) but not to the other pins.

## HIGH ENERGY RADIATION

Device parameters may begin to change if subject to an ionising dose of greater than  $10^4$  rads.

Certain characterisation data are held at Marconi Applied Technologies. Users planning to use CCDs in a high radiation environment are advised to contact Marconi Applied Technologies.

## TEMPERATURE LIMITS

	Min	Typical	Max	
Storage . . . . .	73	-	373	K
Operating . . . . .	73	273	323	K

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

**Maximum device heating/cooling . . . . . 5 K/min**

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