Characteristics and use of Opto-Hybrid photodetectors

CENTRONIC OPTO-HYBRID PHOTODETECTORS. (PHOTODIODE/AMPLIFIER COMBINATIONS)

With our range of Opto-hybrid Photodetectors, Centronic Ltd. has aimed to produce devices that allow the maximum flexibility, and yet require the minimum of technical effort on the part of the user. This has been achieved by the careful design of amplifier stages that are well matched to the photodiodes used. The outputs are generally low impedance voltage sources, which may be used directly for some applications. Alternatively these signals can be easily amplified using simple operational amplifier circuits, if higher signal levels are required.

The combination of a photodiode together with the first stages of amplification within the same package is of particular advantage in situations where there are space limitations or where noise is likely to be a problem. In the latter situation the influence of external sources of noise or electrical interference are minimised through the reduction in length of the highly sensitive input line to the amplifier and its effective screening by the package. Amplifier noise effects are minimised by the reduction of stray capacitance on its input, which is possible with a hybrid design.

The choice of a detector/amplifier hybrid to suit a particular application is determined by a number of considerations, such as the maximum and minimum signal levels, the operating wavelength, the required signal to noise ratio and frequency response.

Centronic offers two basic types of hybrid circuit based on either an operational amplifier used in the transimpedance configuration or a video amplifier. As an additional variant the photodiode may be biased or unbiased.

Generally a transimpedance amplifier used in conjunction with an unbiased photodiode will give the lowest dark offset, lowest noise and hence the lowest detectable signal and will also accept a higher signal before saturation. A video amplifier circuit with a biased photodiode will give higher speed, generally at the expense of higher noise and a lower saturation level.

A selection chart showing the range of standard hybrid photodetectors offered by Centronic is presented in the following pages. It will be seen that for a given detector area there are certain trade offs between detector sensitivity, dynamic range, bandwidth and noise level. The following notes covering certain design considerations provide additional background information which will help the user in establishing the best device for his needs. If a standard detector is unsuitable then Centronic can produce a custom designed product.

DESIGN CONSIDERATIONS

1. CIRCUIT ALTERNATIVES

(a) The Transimpedance Circuit.

In the transimpedance circuit an operational amplifier is used with negative feedback in such a way that the current generated by the photodiode is converted via the resistor into an output voltage, the general format being as shown in figure 1.

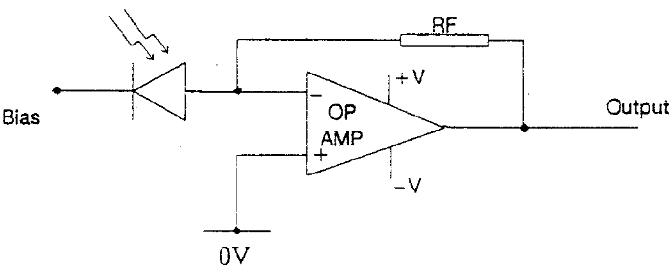


Fig:1 TRANSIMPEDANCE AMPLIFIER CONFIGURATION

In cases where high speed is not required the bias terminal can be connected to 0V internally. The feedback resistor has a capacitor connected across it to define the upper cutoff frequency, as well as to stabilise the configuration.

The gain of a transimpedance amplifier is defined only in terms of the feedback resistor. So, for example, if a hybrid has a feedback resistor of 1 Mohm, then its transimpedances gain will be given as 1 Mohm, thus if the photodiode has a responsivity of 0.4 A/W the output from the amplifier will be 4×10^5 V/W(0.4V/uW).

Centronic Limited, Centronic House, King Henry's Drive, New Addington Croydon CR9 0BG U.K
Telephone 0689 42121 Facsimile no: 0689 45117 Telex no: 896474 Centro G

(b) Video Amplifier Circuits.

The second type of hybrid uses a video amplifier to amplify the voltage dropped across a load resistor due to the current generated by the photodiode. The general format is shown in figure 2.

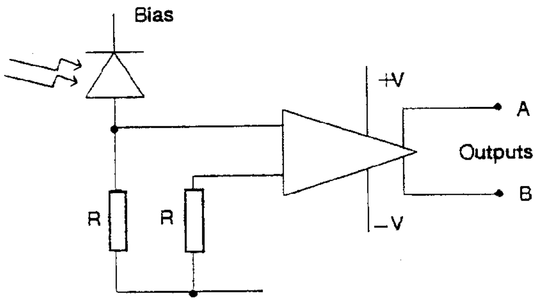


FIG:2 VIDEO AMPLIFIER CONFIGURATION

Although the noise of such a system is generally greater for a given bandwidth, higher speeds can be achieved.

The gain for such a system is defined by the value of resistor R multiplied by the fixed gain of the amplifier. So for example if the amplifier has a gain of 100 and R is 1 kohm then its gain would be given as 100 kohm and with a diode of 0.4 A/W would give an output sensitivity of 4×10^4 V/W. The two outputs provided can either be used in a differential mode or as single outputs with respect to zero volts.

2. BANDWIDTH LIMITATIONS

A photodiode when used in the photovoltaic mode will have a slow response because the majority of hole-electron pairs produced by the incident light are situated beyond the diode depletion region and hence will travel by diffusion without the aid of an electric field. Typical rise times (10% to 90%) in this mode are about 5us with a typical response curve for a step input as shown in figure 3.

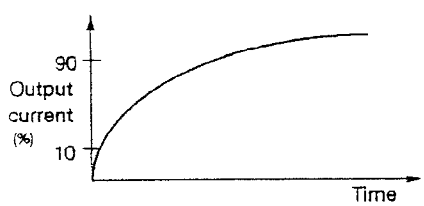


Fig:3
TYPICAL PHOTODIODE STEP RESPONSE CURVE

The waveform generated does not follow the normal exponential shape expected from a pure RC network and thus care must be taken in the use of the usual rise time-bandwidth product relationship, TBW = 0.35.

Where possible, opto-hybrids are designed so that the feedback time constant is larger than the diffusion component, thus controlling these characteristics.

By applying bias to a photodiode, the depletion region is increased resulting in (A) greater depth for fast hole-electron pair collection and (B) reduced photodiode capacitance.

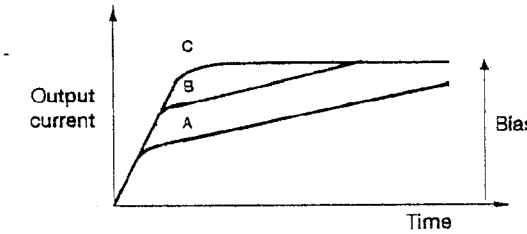


Fig:4 PHOTODIODE STEP RESPONSE VS BIAS

For a given resistivity of silicon and a stated wavelength, a typical family of curves shown in figure 4 above can be generated. (A) being with the lowest bias and (C) with the highest. Hence where high speed is required, applying bias has a positive effect. Once the depletion depth is sufficient for approximately 98% of the hole-electron pairs to be generated within this region, there is little advantage to be gained in increasing the bias still further.

The high speed opto-hybrids are designed so that the feedback elements will be effective towards the higher bias conditions. In this instance the family of curves would be as shown in figure 5.

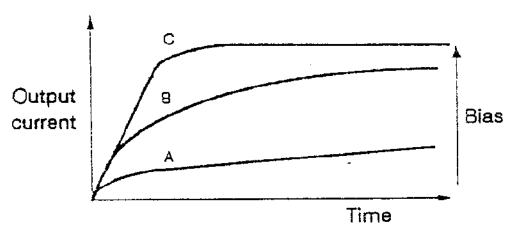


Fig:5 OPTO-HYBRID STEP RESPONSE VS BIAS

Where only curve C follows the feedback network controlled RC waveform.

For a given resistivity of silicon the bias can be altered depending on optical wavelength to give a constant rise time, as shown *in figure 6.*

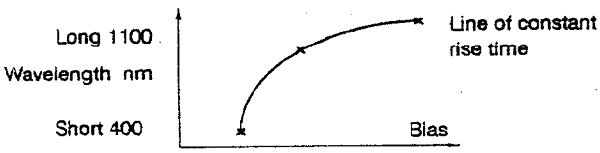


Fig:6
WAVELENGTH VS BIAS FOR CONSTANT RISE TIME

The required bias can become very large i.e.approximately equal to 200V for the longer wavelengths, therefore thinned photodiodes can be used so that full depletion occurs at a lower voltage. The disadvantage of this being that the CW responsivity is reduced.

3. APPLICATION NOTES.

Generally, the supply lines to a hybrid will require capacitive decoupling to the OV or ground line, although the faster devices have some built-in decoupling. Refer to the relevant data sheets. Without adequate decoupling the device is likely to oscillate, rendering it temporarily inoperative. This decoupling should take the form of a 10nF to 100 nF ceramic capacitor in parallel with a 1uF tautalum capacitor, between the supply lines and OV, see figure 7.

The noise figures stated for the wide bandwidth hybrids are measured with an output filter, as stated in the relevant data sheets. The noise figures for the remaining devices may be reduced, from those stated, by using a low-pass output filter, with a cut-off frequency somewhat higher, than the bandwidth of the hybrid. This filter has the effect of reducing the noise bandwidth, which normally extends well beyond the signal bandwidth, see figure 8.

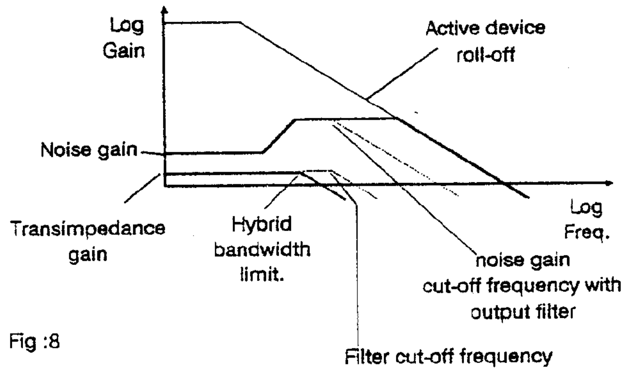


Fig :8

IDEALISED BODE PLOT FOR A TRANSIMPEDANCE AMPLIFIER/ PHOTODIODE COMBINATION, SHOWING THE EFFECT ON THE NOISE GAIN OF AN OUTPUT FILTER.

The filter will also have the effect of increasing the rise time of the whole arrangement, as follows:-

$$t_T = (t_h^2 + t_f^2)^{1/2}$$

assuming a single lag filter. Where, t_T is the total rise time after the filter, t_h is the rise time of the hybrid and t_f is the equivalent rise time of the filter. Therefore, if the cut-off frequency of the filter is 3 times the bandwidth of the hybrid, the rise time is degraded by less than 6%. The filter may be implemented by the user, by inclusion into any subsequent gain stages or signal processing stages of their system, see figure 7.

A peak to peak value is approximately equal to 6 times the RMS value.

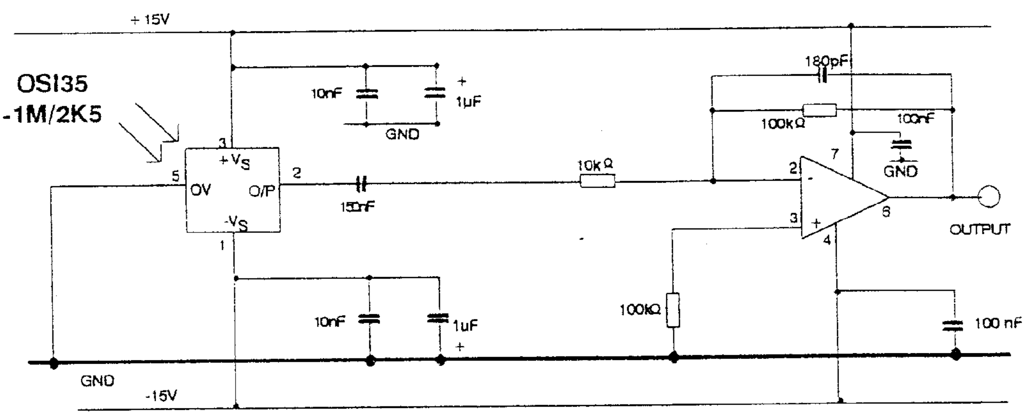
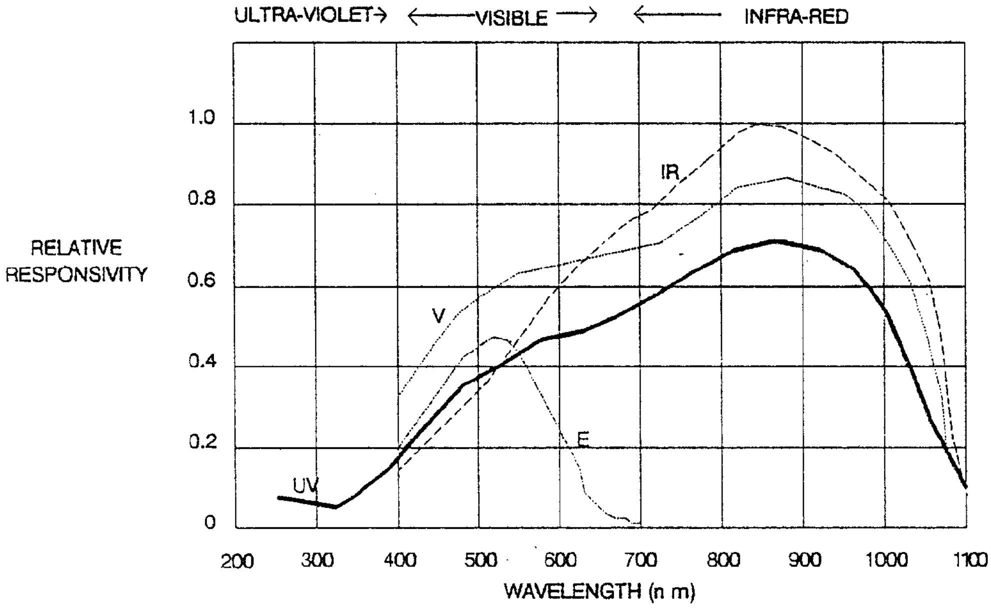


Fig:7
TYPICAL AC COUPLED ARRANGEMENT, WITH A SINGLE LAG FILTER CHARACTERISTIC BUILT INTO THE AMPLIFICATION STAGE.

4. ANTI - REFLECTION COATINGS

An anti-reflection coating is applied to the silicon to help improve the response characteristics for a particular wavelength.

Visible(V) and Infra-red(IR) responses are offered on the full range of opto-hybrid detectors. Ultra-violet(UV) and eye (E) responses are offered only on some devices as shown in the selection chart.



5. CLASSIFICATION

Centronic photodiode and amplifier combinations are designated OSI for single element requirements, LDH for two or more elements as a linear array requirement, MDH for matrix element requirements and QDH for quadrant requirements.

XXX	XXX —	XX —	XXX /	XXX
↑	↑	↑	↑	↑
Device type OSI LDH QDH MDH	Active area (OSI & QDH) NUMBER OF ELEMENTS (LDH & MDH)	Spectrum UV V IR E	TRANSIMPEDANCE Gain in ohms	Upper cut -off frequency

EXAMPLE:
OSI35-V-1M/2K5

The following pages give standard product availability. If this product range does not meet your requirements then call us and we can discuss your requirement to see whether a standard product can be modified and/or a special custom device made.

Handling Precautions

Optical cleaning

Although photodiodes in packages or in chip form are reasonably rugged, care should be taken when handling them, such as avoid touching windows or chips with bare fingers.

To clean a detector, any dust or loose particles should first be blown away using dry compressed gas. The detector surface or window can then be cleaned using a lens tissue moistened with ethyl alcohol wiped lightly over the surface. Any other cleansing agents could cause deterioration of the detector's resin coating or filter and should be avoided.

Soldering

Photodiodes are susceptible to damage from excess heat during soldering of the package leads. Soldering temperature and time must be minimized to protect the diode but, long enough and high enough for a proper solder joint. Metal case devices should be soldered at 300°C for 15 seconds, ceramic case devices at 300°C for 10 seconds and plastic case devices at 300°C for 5 seconds. Package heating can be minimized by clamping a heat sink (tweezers) onto the package lead being soldered, between the solder joint and the package.

What is UV-radiation?

Ultra-violet radiation forms part of the electromagnetic spectrum and is invisible to the naked eye.
UV-radiation is defined by the spectral region 100-400 nm and terminates in the blue portion of visible light (400-780 nm).
The shorter the wavelength of UV-radiation the greater the energy. Penetration is also wavelength dependant. As wavelength increases depth of penetration increases.
The largest natural source of UV-radiation is the sun which plays an important role in sustaining life on earth.

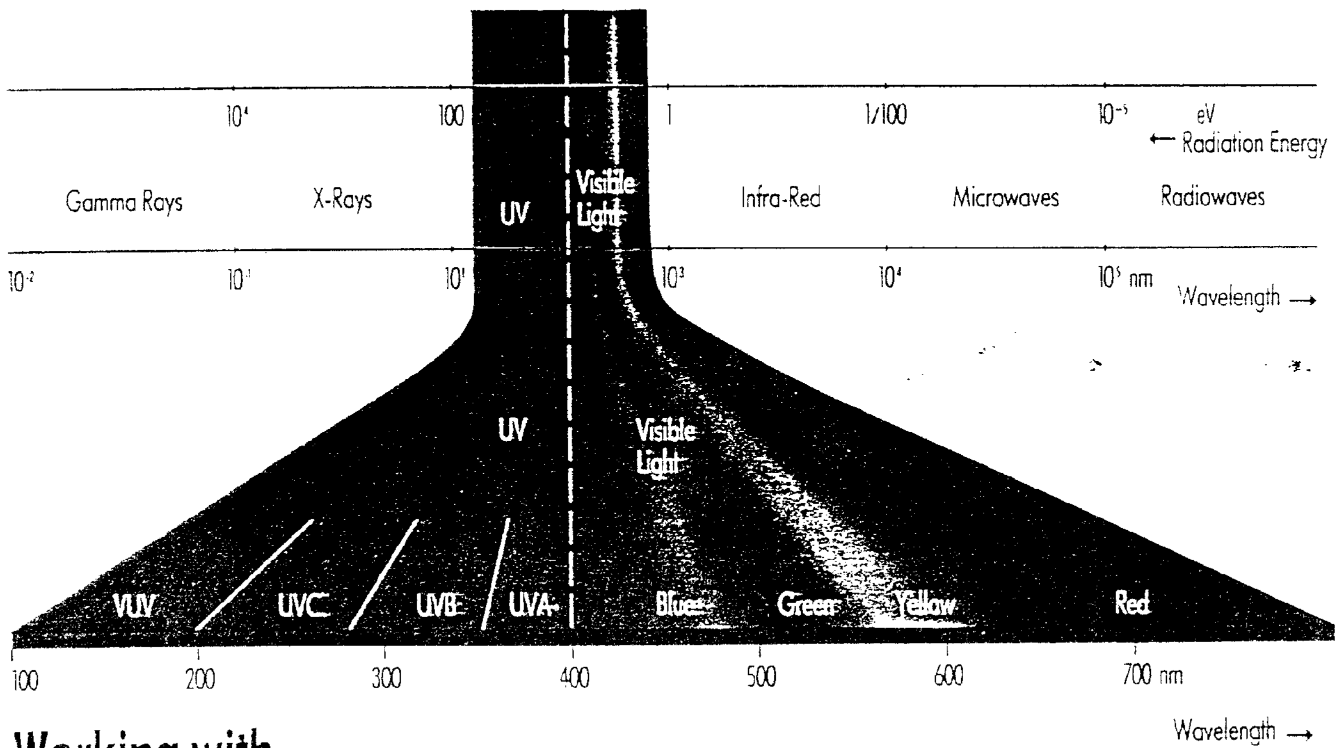
The effects of UV-radiation

UV-radiation initiates photo-chemical reactions and depending on the energy different effects occur.
The energy of UV-radiation is dependant on wavelength. It is therefore necessary to subdivide into the following specific wavelength regions.

- **UVA-RADIATION (400-315 nm)**
- **UVB-RADIATION (315-280 nm)**
- **UVC-RADIATION (280-200 nm)**
- **VUV-RADIATION (200-100 nm)**

The most important region for curing of UV plastics and adhesives is UVA-radiation. This type of UV-radiation is also used for fluorescent examination of materials.
UVB is the most energetic component of natural sunlight and plays an important role in the artificial accelerated ageing of materials.
UVC has sufficiently high energy to kill micro-organisms and is consequently employed for sterilization of air, water and packaging materials.
This type of UV-radiation is also used for rapid drying of UV inks and lacquers.

The electromagnetic radiation spectrum



Working with UV-radiation

UV-radiation is more energetic than longer wavelength visible light. Consequently, bad design or incorrect use of UV equipment can result in damage to skin and eyes.
UVA-radiation has been shown by scientific research to be harmless. UVB and UVC-radiation can lead to long term accute damage to skin and eyes. However, these radiation regions are necessary for some applications and therefore stringent safety precautions must be taken.

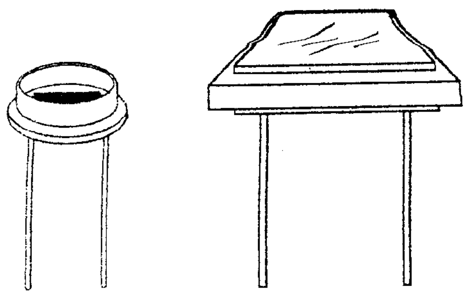
All Dr. Hönle machines are manufactured stricly in accordance with recommendations by the German Department of Health and Safety at Work.

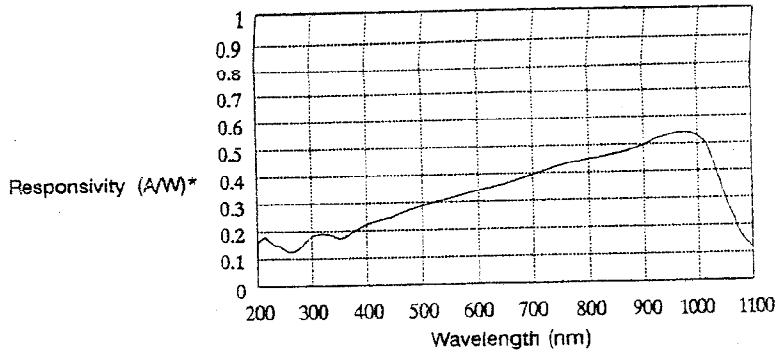
NEW FROM CENTRONIC

CENTRONIC

SUPER U.V PHOTODIODES

The new series 7 photodiodes are designed for high responsivity and shunt resistance in the UV region. It is particularly intended for analytical, light measurement, HPLC, photometry and flourescence applications where sensitivity from 190nm to 400nm is important.





ELECTRICAL/OPTICAL SPECIFICATIONS

Characteristics measured at 22°C (±2)

Type no.	Package	Window Options available	Active area		Responsivity A/W*		Dark current pA $@V_r = 10mV$ Typical	NEP $W/Hz^{1/2}$ Typical $\lambda = 800nm$	Capacitance pF, Typical	Rise time us, $V_r = 0V$ $R_L = 1K\Omega$ Typical	Shunt resistance Gohm $@V_r = \pm 10mV$	
			mm^2	mm	@254nm Typical	@340nm Typical					Minimum	Typical
OSD1.2-7	3	Q,U	1.2	1.1x1.1	0.14	0.19	2	$3x10^{-15}$	40	0.1	0.5	5
OSD5.8-7	2,6	Q,U,O	5.8	2.4x2.4	0.14	0.19	3	$6x10^{-15}$	170	0.4	0.5	3
OSD35-7	1,5	Q,U,O	33.6	5.8x5.8	0.14	0.19	20	$1.5x10^{-14}$	1000	2.0	0.1	0.5
OSD100-7	4	Q,O	100	10x10	0.14	0.19	50	$2x10^{-14}$	3000	6.0	0.03	0.2

*Measured without cover window

Q = Quartz window
O = Open frame (ceramic versions only).
U = UV transmitting glass

For devices with spectral range 190-1100mm, add suffix Q

ORDERING INFORMATION

when ordering use Centronic type number. Please add suffix (Q,U,O) for special requirement i.e.

CERAMIC STYLE PACKAGE — Series, Quartz window

OSD 35-7 CQ

Active area mm^2 — Ceramic package

METAL STYLE PACKAGE — Series, UV glass

OSD 35-7 U

Active area mm^2

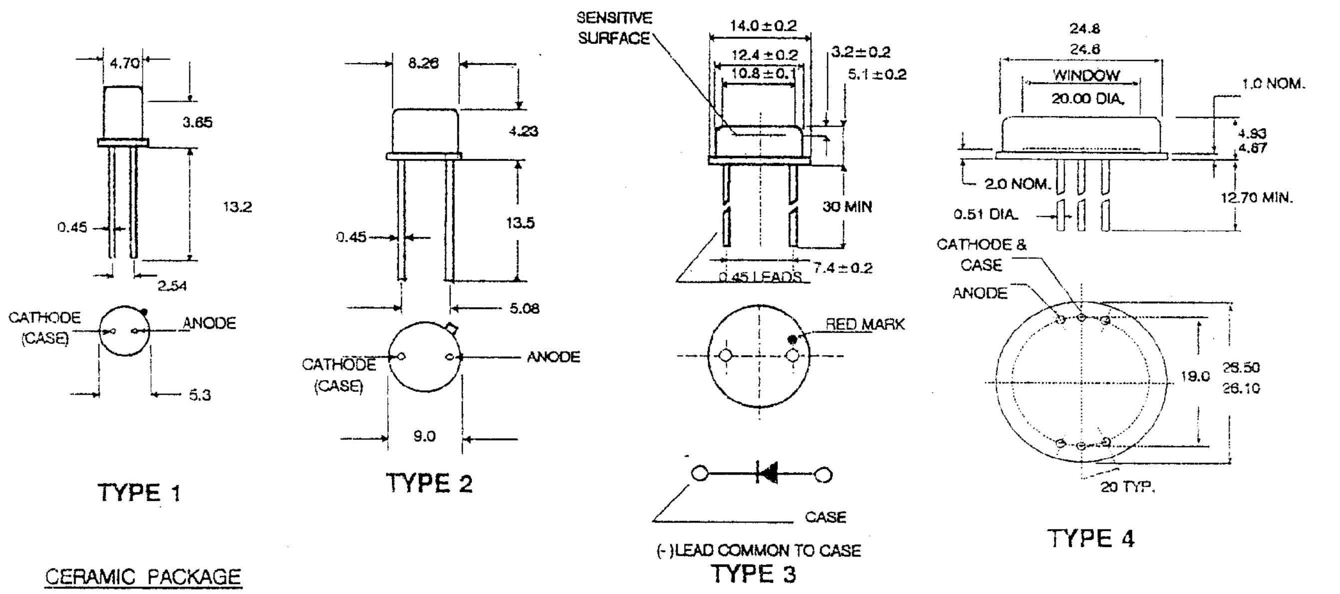
CENTRONIC LIMITED
Centronic House, King Henry's Drive, New Addington, Croydon CR9 0BG, England
Telephone: Lodge Hill (0689) 842121 Fax: (0689) 849711 Telex: 896474 Centro G

CENTRONIC

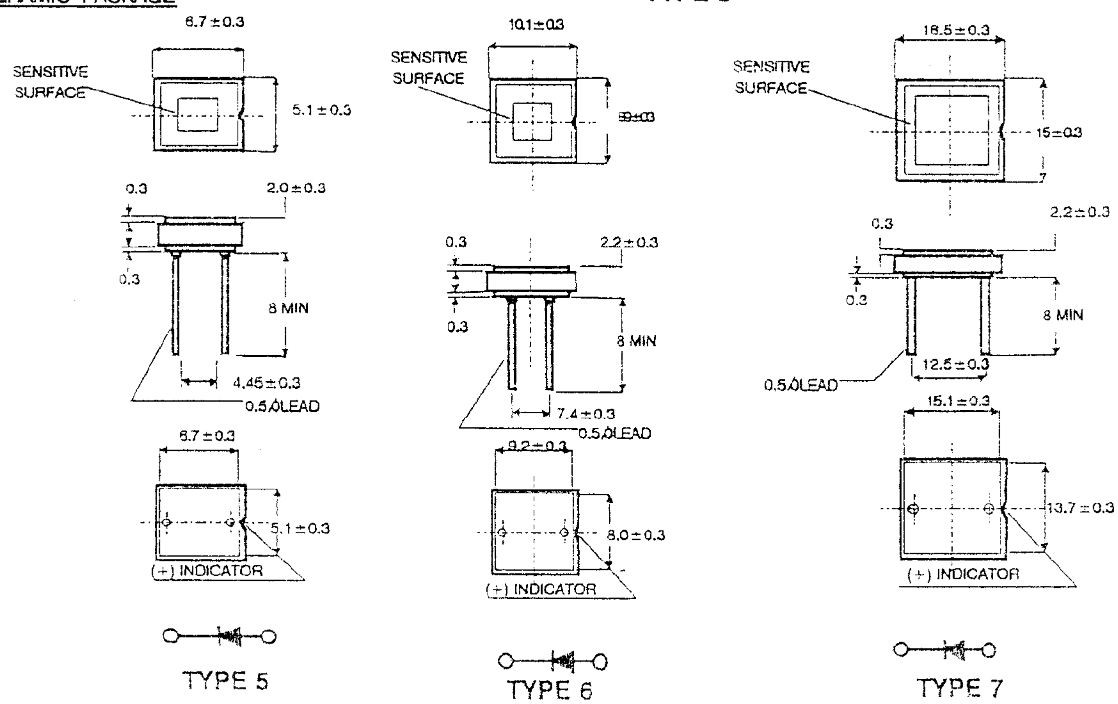
ABSOLUTE MAXIMUM RATINGS

	Max Rating	Unit
DC Reverse Voltage	5	V
Peak pulse current (1us, 1% duty cycle)	200	mA
Peak DC current	10	mA
Storage temperature range	-55 to +125	degree C
Operating temperature range	-55 to +70	degree C
Soldering temperature (2mm from the case for 100)	260	degree C

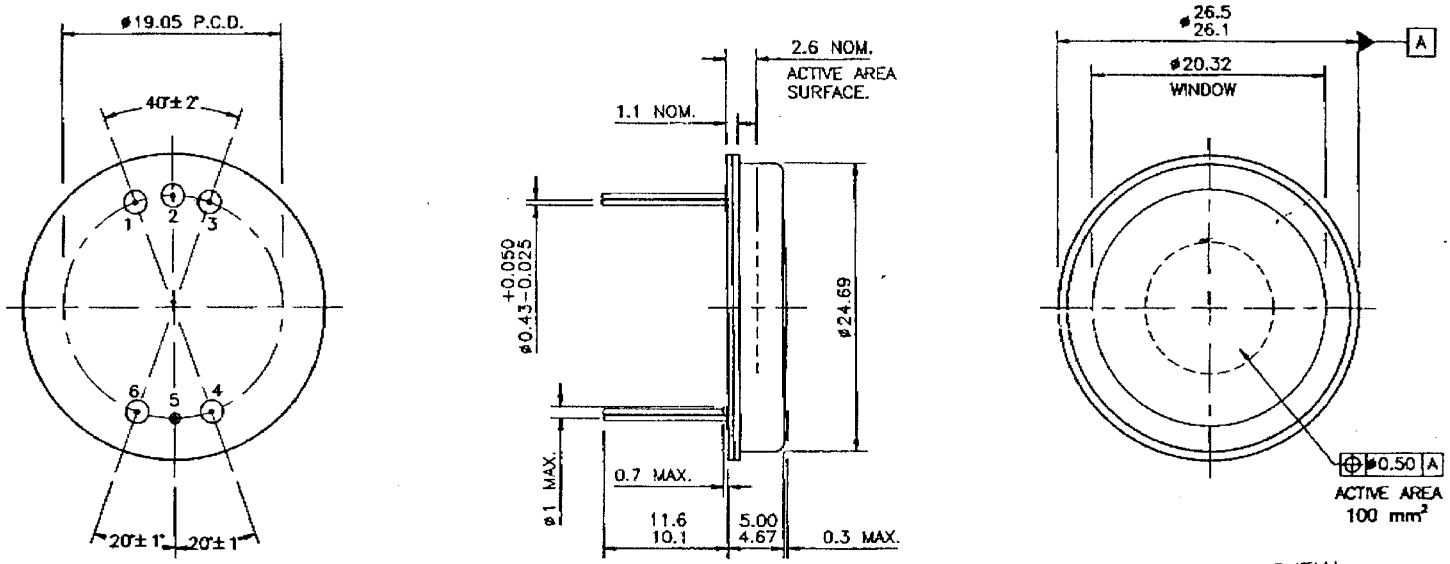
METAL PACKAGE



CERAMIC PACKAGE



WARNING!
STATIC SENSITIVE DEVICES



PIN ASSIGNMENT

1. N/C
2. OUTPUT
3. +Vs
4. N/C
5. GROUND/CASE
6. −Vs

THIS COPY WILL NOT BE AUTOMATICALLY UPDATED INTENDING USERS SHOULD CHECK THAT THIS ISSUE IS STILL VALID

PROD. APP.	MATERIAL	DIMNS:	mm
DES. APP.		TOLERANCE:	±0.13, U.O.S.
Q.A. APP.	FINISH	SCALE:	3:1
DRAWN		BS 308 THIRD ANGLE	

ISSUE	1							
APPROVED	—							
MOD.No.	—							
DATE	1.7.91							

TITLE: OSI 100 RS PACKAGE DETAILS

CENTRONIC
NEW ADDINGTON
CROYDON
SURREY CR9 0BG

DRAWING No. UK/91628-01