OPTO-ELECTRONIC DEVICES

CONTENTS

50p

MS SERIES

SILICON MESA PHOTOCELLS

A range of silicon photovoltaic cells of mesa construction available in sizes from micro-miniature to large active area for general purpose use.

Unencapsulated cells are coated with a special varnish to protect against contamination and moisture ingress.

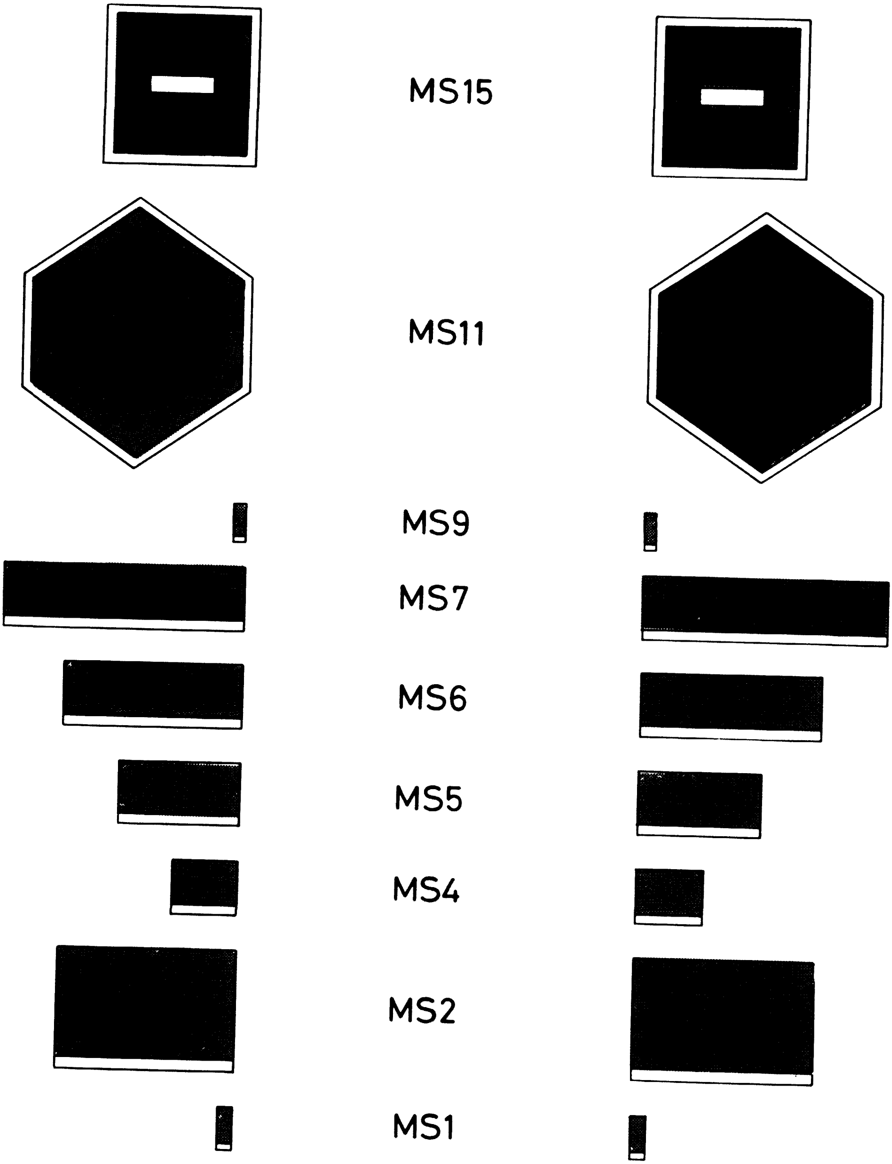
Encapsulated cells are set into tough bakelite or epoxy housings with stud or pin mountings (suffix E).

Devices are graded for standard use under both high (suffix A) and low (suffix B) light levels.

TYPICAL CHARACTERISTICS (at 25°C)

Type	Active Area mm	3000 lumens/sq. ft. Voc mV	3000 lumens/sq. ft. Isc mA	200 lumens/sq. ft. Voc mV	200 lumens/sq. ft. Isc mA	Comments
MS1A	3·48 × 1·83	500	1·0	—	—	Miniature for punched tape or punched card reading systems
MS1AE	3·48 × 1·83	500	1·0	—	—	
MS1B	3·48 × 1·83	500	1·0	350	0·065	
MS1BE	3·48 × 1·83	500	1·0	350	0·065	
MS2A	18·85 × 11·63	500	27	—	—	
MS2AE	18·85 × 11·63	500	31	—	—	
MS2B	18·85 × 11·63	500	31	400	2·0	
MS2BE	18·85 × 11·63	500	34	400	2·3	
MS4A	6·15 × 5·26	500	5	—	—	Photovoltaic for high and low light level applications
MS4B	6·15 × 5·26	500	5	350	0·33	
MS5A	12·5 × 5·26	500	10	—	—	
MS5B	12·5 × 5·26	500	10	350	0·66	
MS6A	18·85 × 5·26	500	15	—	—	
MS6B	18·85 × 5·26	500	15	350	0·99	
MS7A	25·2 × 5·26	500	20	—	—	
MS7B	25·2 × 5·26	500	20	350	1·32	
MS9A	2·13 × 0·99	500	0·3	—	—	Micro-miniature for punched tape or punched card reading systems for high light level applications
MS9AE	2·13 × 0·99	500	0·3	—	—	
MS9B	2·13 × 0·99	500	0·3	350	0·02	
MS9BE	2·13 × 0·99	500	0·3	350	0·02	
MS11A	23·4	500	48	—	—	Large area photovoltaic
MS11AE	23·4	500	54	—	—	
MS11B	23·4	550	54	330†	3·6	
MS11BE	23·4	550	60	330†	4·0	

†Minimum.



MS RANGE OF SILICON PHOTOCELLS

MS-15 INFRA-RED PHOTOCELL

This silicon photocell has been specifically developed for the detection of Infra-red radiation in the wavelength range 0.75 to 1.1 microns. Originally used in conjunction with a Helium Neon laser for the simulation of gun-fire in a training target system, the MS15 can be used in a wide range of more general applications where the detection of Infra-red radiation is necessary. The MS15 is ideally suited for the sensing of Gallium Arsenide l.e.d.s or filtered tungsten light sources in most detection and alarm systems. A low value of junction capacitance means that the MS15 has a high speed of response. (Photograph of MS15 on Page 3).

TYPICAL CHARACTERISTICS (at 25°C)

Type	Active Area	Min. Reverse Resistance $V_R = 4{\cdot}5V$	Max. cj V = 0 f = 1 kHz	Minimum Open Circuit Voltage Source Intensity (foot candles) *			Peak Spectral Response
	mm	ohms	pF	0·5	1·0	1·5	0·9μ
MS15	12·7 × 12·7	75000	8000	28 mV	35 mV	40 mV	

*This is the illumination intensity of a tungsten source at 2870°K; cells covered with 2 mm thickness of Chance Bros. infra-red filter type OX5; radiation limited to wavelengths beyond 0·75 μm.

SILICON PLANAR PHOTOTRANSISTORS

GENERAL APPLICATIONS OF FERRANTI PHOTOTRANSISTORS

Alarm Systems, Process Control, Edge and Position Sensing, Optical Character Recognition, Tape Readers, Card Readers, Electronic Flash Control, etc.

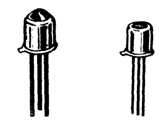
Silicon Planar Photo-transistor **BPX25,29**

DESCRIPTION

High sensitivity silicon planar photo-transistors in hermetic packages for general purpose applications.

The BPX25 has a glass lens.

The BPX29 has a plane glass window.



ABSOLUTE MAXIMUM RATINGS (both types) at 25°C ambient temperature.

Parameter		Symbol	Max.	Unit
Collector-Emitter Voltage		V_{CEO}	32	V
Collector-Base Voltage		V_{CBO}	32	V
Emitter-Base Voltage		V_{EBO}	5	V
Peak Collector Current		I_{CM}	200	mA
Collector Current		I_C	100	mA
Power Dissipation	BPX25 BPX29	P_{tot}	300 180	mW mW
Operating and Storage Temperature Range	BPX25 BPX29		−40 to +150 −40 to +100	°C °C

BPX25/29

ELECTRICAL CHARACTERISTICS (at 25°C ambient temperature unless otherwise stated).

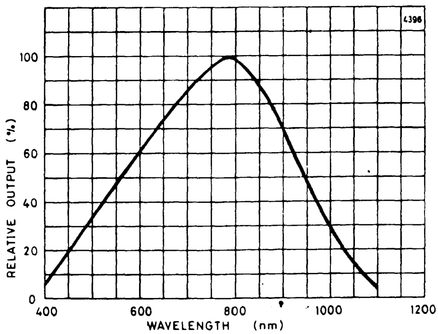
Parameter	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Collector dark current	$I_{CE(D)}$		0.025 8.0	0.1 15.0	μA μA	$V_{CE}=24V$ $V_{CE}=24V$ at 100°C ambient temp.
Light current BPX25 BPX29	$I_{CE(L)}$	5.0 0.25	13.0 0.8		mA mA	Tungsten source. Colour temp. =2700°K. Light level=1000 Lux. $V_{CE}=6V$
Static forward current transfer ratio	h_{FE}		500			$V_{CE}=6V$, $I_C=2mA$
Rise time (10 to 90%) BPX25	t_r	–	1.5	3.0	μs	See notes 1 and 2 and graphs of switching characteristics
BPX29		–	3.0	6.5	μs	
Fall time (90 to 10%) BPX25	t_f	–	1.5	4.0	μs	See notes 1 and 2 and graphs of switching characteristics
BPX29		–	3.8	8.0	μs	
Wavelength of peak spectral response		–	0.8	–	μm	
Cut-off frequency BPX25		–	200	–	kHz	See notes 1 and 2
BPX29		–	100	–	kHz	
Thermal characteristics	$\theta_{j\text{-}c}$ $\theta_{j\text{-}a}$	– –	0.15 0.40	– –	°C/mW °C/mW	
Noise equivalent illumination BPX25 BPX29		– –	0.5 1.5	– –	mLux/Hz-½ mLux/Hz-½	1000lux., $V_{CE}=5V$, f=800 Hz See note 3

1 Gallium Arsenide lamp emitting modulated radiation at approximately 0.4 mW/cm^2, phototransistor used under optimum load conditions (50Ω load) with $V_{CE}=24V$.

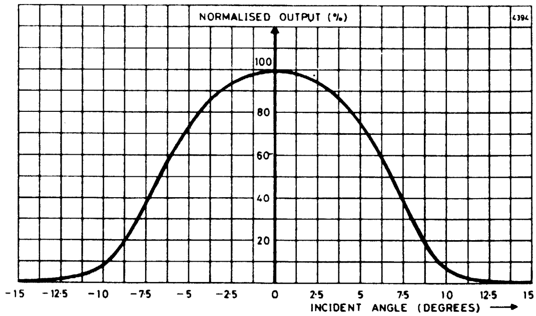
2 Improved switching times may be achieved by connecting the base lead to give a quiescent bias current. Typically, at $I_B=20\mu A$, t_d is reduced from 1.0 to <0.2 μs.

3 At this and lower frequencies $1/f$ noise predominates.

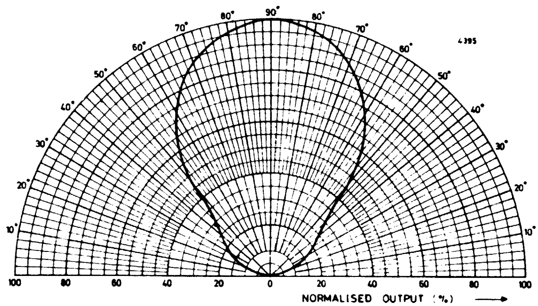
RELATIVE SPECTRAL RESPONSE BPX25 & BPX29



TYPICAL POLAR RESPONSE BPX25

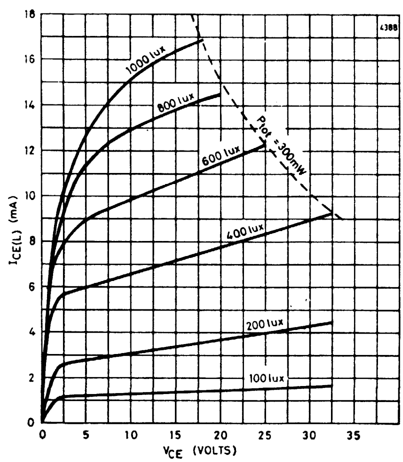


TYPICAL POLAR RESPONSE BPX29

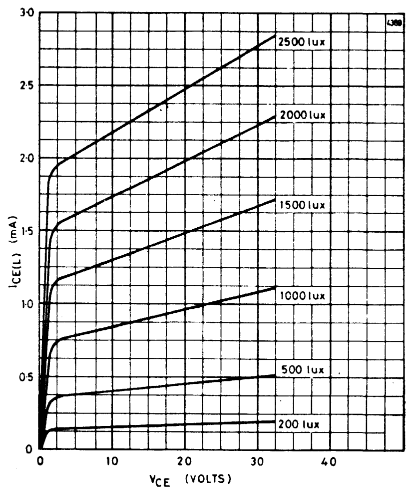


TYPICAL OUTPUT CHARACTERISTICS

BPX25

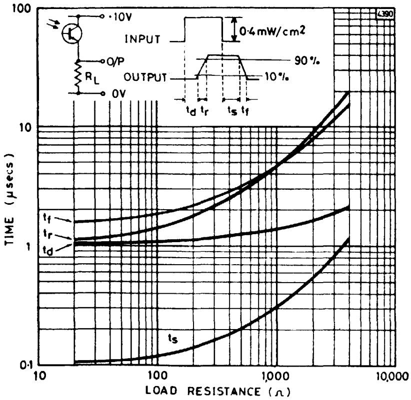


BPX29

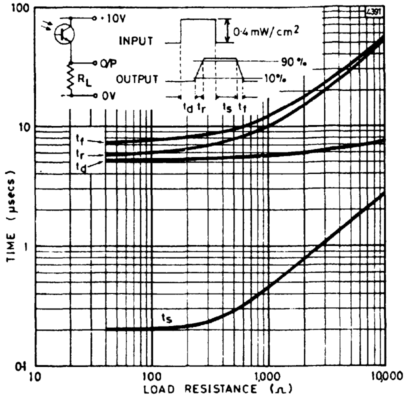


TYPICAL SWITCHING CHARACTERISTICS

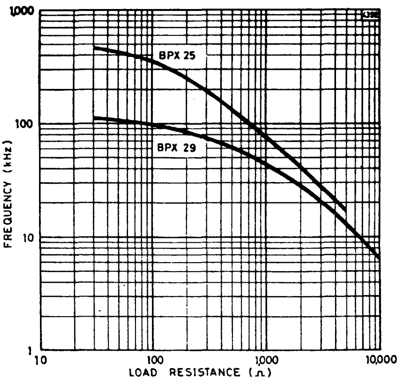
BPX25



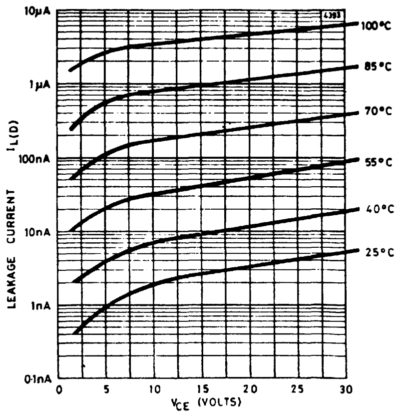
BPX29



BPX25 & BPX29



BPX25 & BPX29

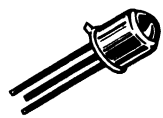


ZM100, 110

An NPN Silicon Planar phototransistor or photodarlington in an hermetically sealed TO-18 based encapsulation with a glass lens.

This package provides a high illumination sensitivity together with a narrow acceptance angle for improved discrimination.

ZM100 – Photodarlington **ZM110 – Phototransistor**



TO-18

ABSOLUTE MAXIMUM RATINGS (at 25°C ambient temperature).

Parameter		Symbol	Max.	Unit
Collector-Base Voltage		V_{CBO}	35	V
Collector-Emitter Voltage		V_{CEO}	35	V
Emitter-Base Voltage	ZM100	V_{EBO}	10	V
	ZM110		5	V
Total Power Dissipation		P_{tot}	300	mW
Operating and Storage Temperature Range		–40 to +150		°C

ZM100, 110

CHARACTERISTICS (at 25°C ambient temperature).

Parameter	ZM100			ZM110			Unit	Conditions
	Min.	Typ.	Max.	Min.	Typ.	Max.		
Collector dark current at 25°C	—	—	1	—	—	0.025	μA	$V_{CE} = 10V$, $I_B = 0$
at 100°C	—	—	500	—	—	10	μA	$E_V = 0$
Collector-emitter illumination sensitivity	750	2000	—	—	—	—	μA/lum./ft²	$V_{CC} = 10V$, $E_V = 2$ lum./ft², $R_e = 1000\Omega$ (see note 1)
	—	—	—	100	200	—	μA/lum./ft²	$V_{CC} = 10V$, $E_V = 10$ lum./ft², $R_e = 100\Omega$ (see note 1)
Rise time, t_r (10% to 90%)	—	—	400	—	—	4.0	μs	(See note 2 and relevant graph)
Fall time, t_f (90% to 10%)	—	—	400	—	—	4.0	μs	
Peak of spectral response	—	0.78	—	—	0.78	—	μm	

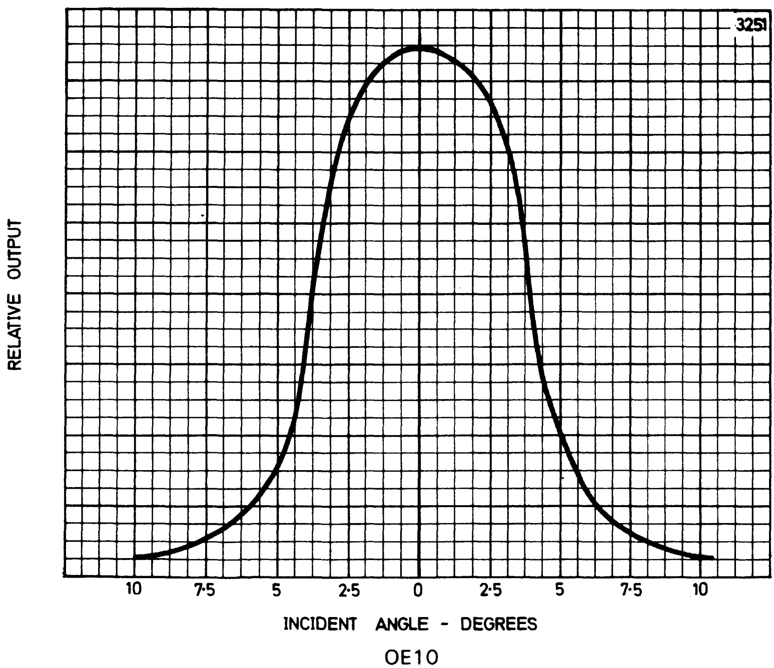
Notes:

1 The illumination source is a tungsten filament lamp at 2856°K.

2 The illumination source is a Gallium Arsenide light-emitting diode adjusted to produce a peak emitter current of 1 mA in the phototransistor under test.

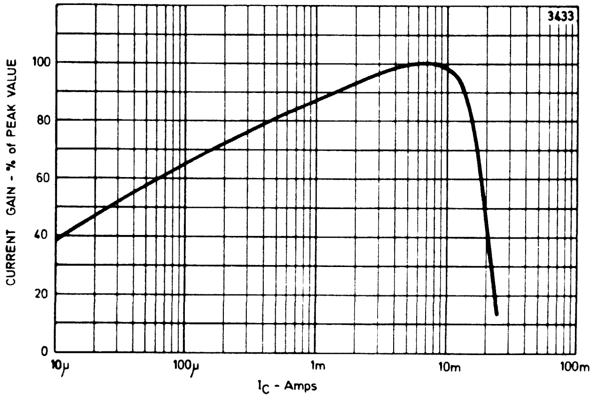
TYPICAL CHARACTERISTICS

Polar Response (both devices)

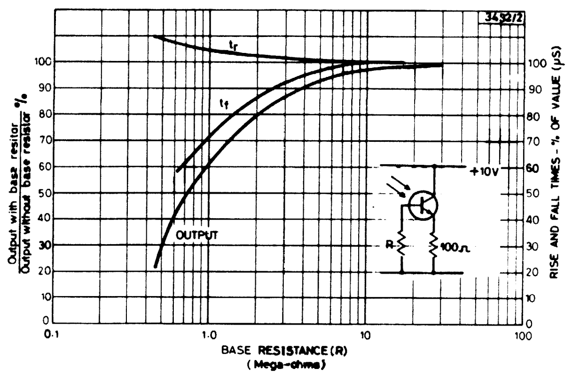


TYPICAL CHARACTERISTICS

ZM110 Current Gain v Collector Current

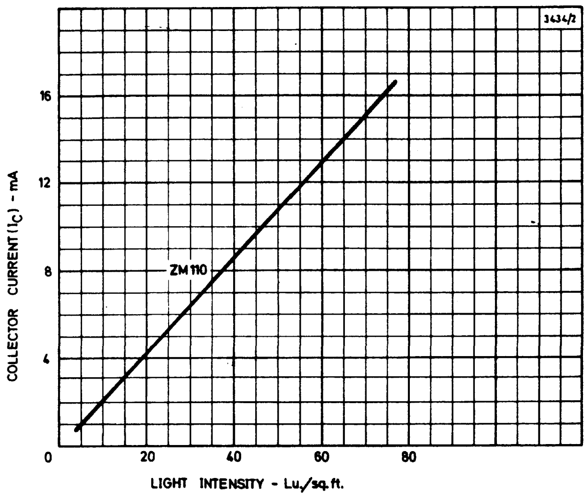


ZM110 Rise and Fall Time v Base Resistance

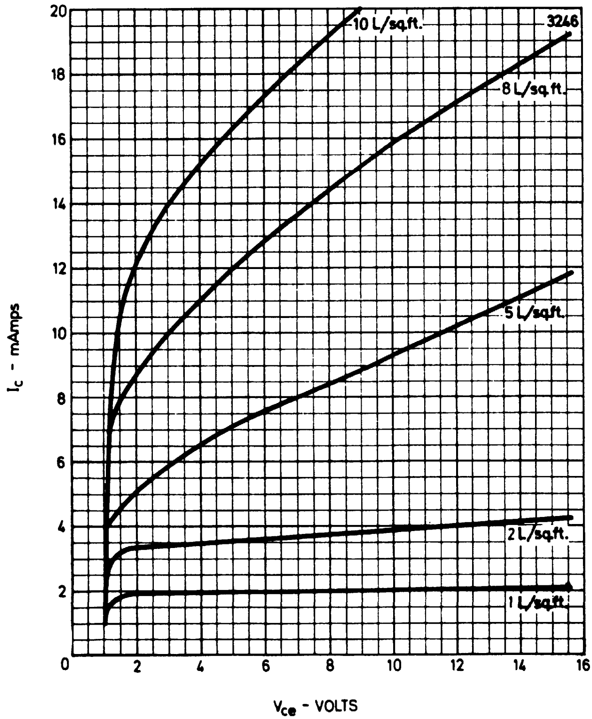


TYPICAL CHARACTERISTICS

ZM110 Collector Current v Light Intensity

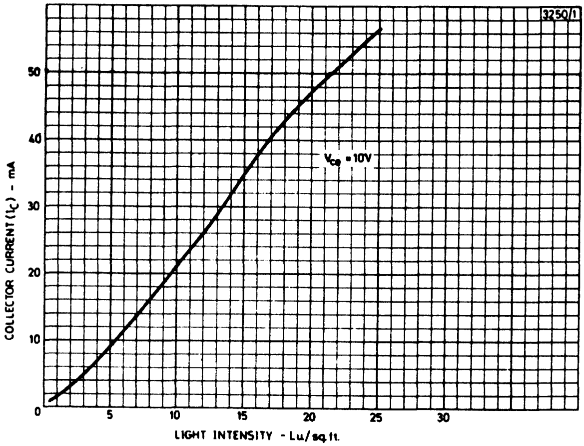


ZM100 Collector Current v Collector-Emitter Voltage

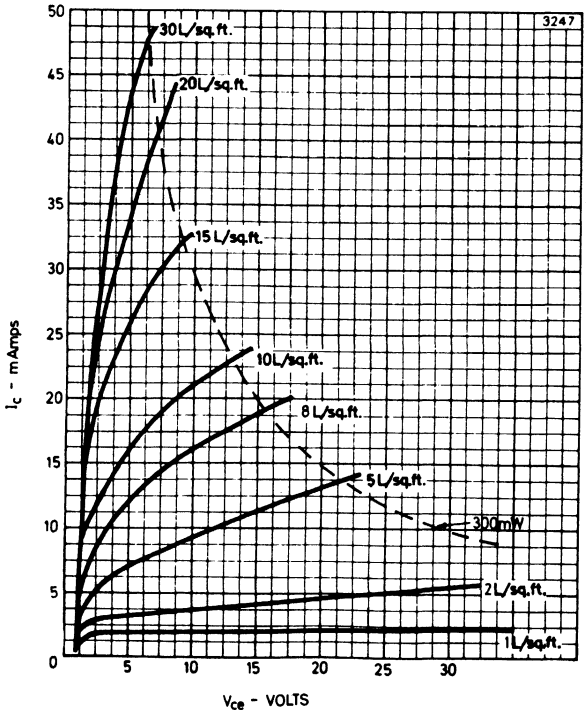


TYPICAL CHARACTERISTICS

ZM100 Collector Current v Light Intensity

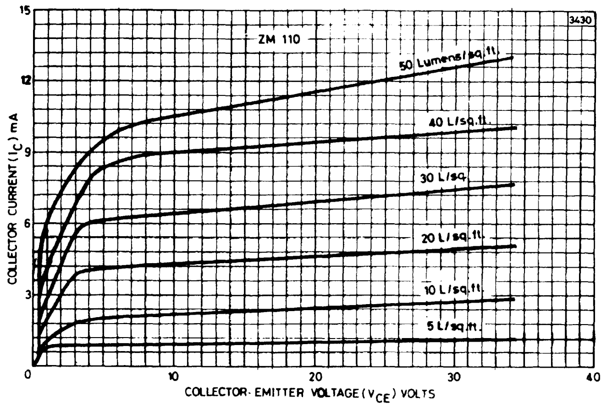


ZM100 Collector Current v Collector-Emitter Voltage

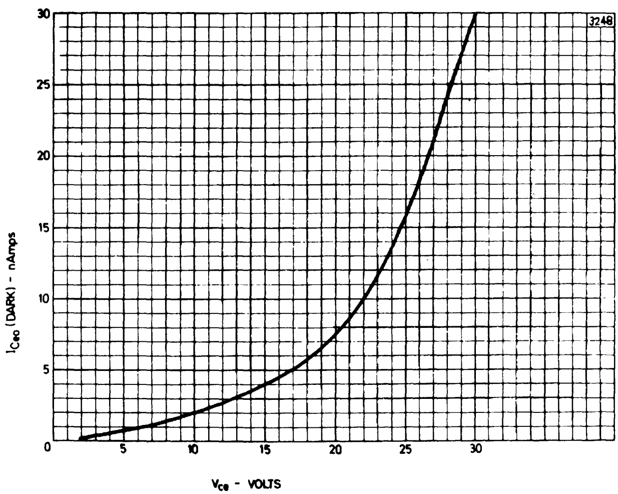


TYPICAL CHARACTERISTICS

ZM110 Collector Current v Collector-Emitter Voltage

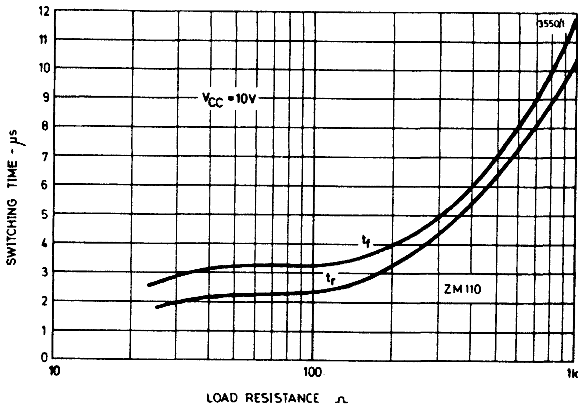


ZM110 Dark Current v Collector-Emitter Voltage

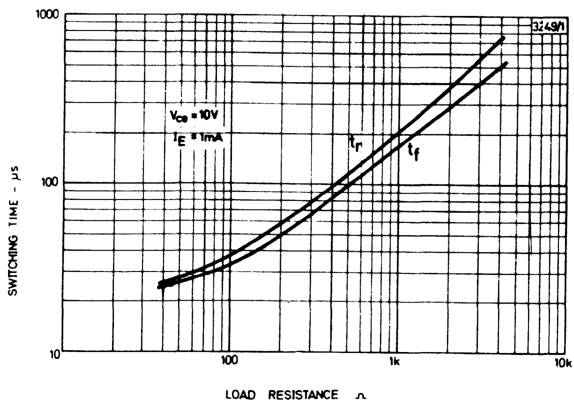


TYPICAL CHARACTERISTICS

ZM110 Switching Time v Load Resistance



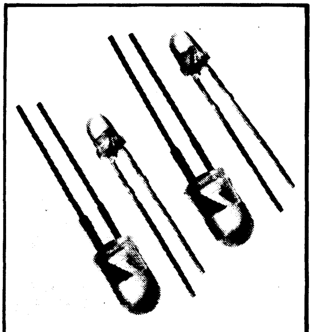
ZM100 Switching Time v Load Resistance



ZM100, 110

ZMP31, 51

A series of phototransistors in an economical, clear plastic, package designed for general opto applications



PLASTIC PACKAGES

ABSOLUTE MAXIMUM RATINGS at 25°C

Parameter	Symbol	Max.	Unit
Collector-Emitter Voltage	V_{CEO}	35	V
Emitter-Collector Voltage	V_{ECO}	6	V
Total Power Dissipation ZMP31 ZMP51	P_{tot}	100 200	mW mW
Operating and Storage Temperature Range	−40 to +85		°C

ELECTRICAL CHARACTERISTICS (at 25°C ambient temperature unless otherwise stated)

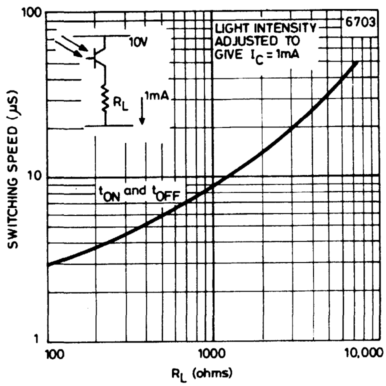
Parameter	ZMP Series			Unit	Conditions
	Min.	Typ.	Max.		
Collector Dark Current at 25°C at 85°C	— —	— —	0.025 10	μA μA	V_{CE} = 10V E_V = 0 lum/sq.ft
Collector-Emitter Illumination Sensitivity (see Note 1)	12.5	30	—	μA/lum/sq.ft	V_{CE} = 10V E_V = 100 lum/sq.ft R_L = 100Ω
Collector-Emitter Saturation Voltage	—	—	0.4	V	I_C = 500μA, I_B = 25μA E_V = 0 lum/sq.ft
Rise Time t_r (10% to 90%) Fall Time t_f (90% to 10%)	— —	— —	4.0 4.0	μs μs	(See Note 2 and relevant graph)
Peak of Spectral Response	—	780	—	nm	

Note 1: The illumination source is a tungsten filament lamp at 2856°K.
Note 2: The illumination source is a gallium arsenide L.E.D. adjusted to produce a peak emitter current of 1 mA in the transistor under test.

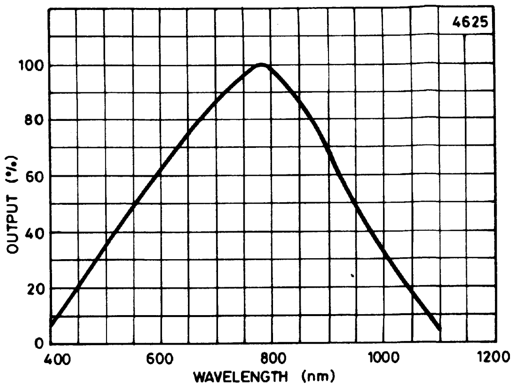
ZMP31, 51

TYPICAL CHARACTERISTICS

ZMP Series Switching Speed/Load Impedance



Relative Spectral Response

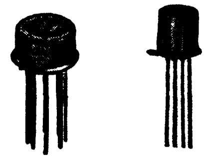


ZNP100 Series

PROGRAMMABLE LIGHT ACTIVATED PHOTOSWITCHES

FEATURES

- **Single 5V supply**
- **Variable sensitivity capability: Operation from 2.9 to 10,000 $\mu W/cm^2$ irradiance levels**
- **Variable or Fixed Hysteresis**
- **TTL compatible output**
- **Output drive of 4.8 mA**



ZNP100 ZNP102-103

GENERAL DESCRIPTION

A monolithic photoswitch device which combines a photodetector, level sensor and output stage to provide a logic output when the light level reaches a preset sensitivity threshold.

CHARACTERISTICS (at 25°C ambient temperature unless otherwise specified).

Parameter	Min.	Max.	Units	Test Conditions
Supply voltage (V_{CC})	4.75	5.25	Volts	
Supply current (I_C)	**16 typ.**	22	mA	$V_{CC} = 5.0V$
Logical 1 output voltage	2.4	—	Volts	$V_{CC} = 4.75V$ $I_L = 120\ \mu A$
Logical 0 output voltage	—	0.4	Volts	$V_{CC} = 4.75V$ $I_{sink} = 4.8$ mA
Light level range of operation ZNP100/2/3	10*	10,000†	$\mu W/cm^2$	See note 1
Capacitive component in time constant	2,200	—	pF	$V_{CC} = 5.0V$
Resistive component in time constant	3	100	kΩ	$V_{CC} = 5.0V$
Maximum switching frequency	**50 typ.**	—	kHz	At 10,000 $\mu W/cm^2$ illumination level
Variation in sensitivity threshold ($\mu W/cm^2$) with V_{CC}	**+5 typ.** **0 typ.** **−5 typ.**	— — —	% % %	$V_{CC} = 5.25V$ $V_{CC} = 5.0V$ $V_{CC} = 4.75V$

*Typical RC = 40k × 100,000 pF. †Typical RC = 3k × 2,200 pF.
Note 1 : The illumination source is an unfiltered tungsten filament at a colour temperature of 2865°K.

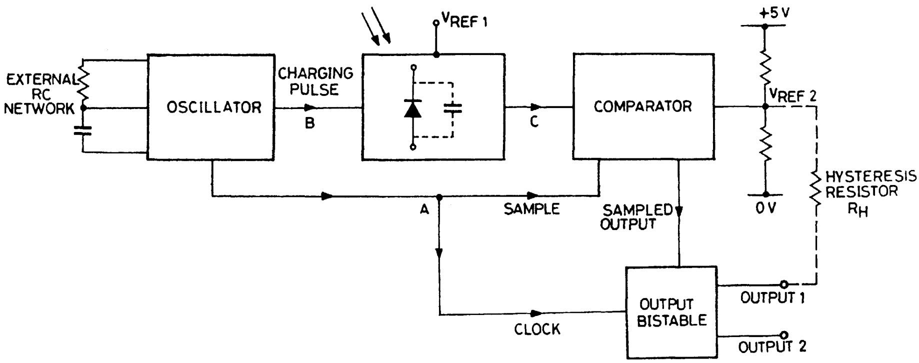
ZNP100 Series

CHARACTERISTICS (at 25°C ambient temperature unless otherwise specified).

Parameter	Min.	Max.	Units	Test Conditions
Variation in sensitivity threshold with temperature	**–0.6 typ.**	—	%/°C	$V_{CC} = 5.0V$
Operating temperature ZNP100/2/3	—	70	°C	

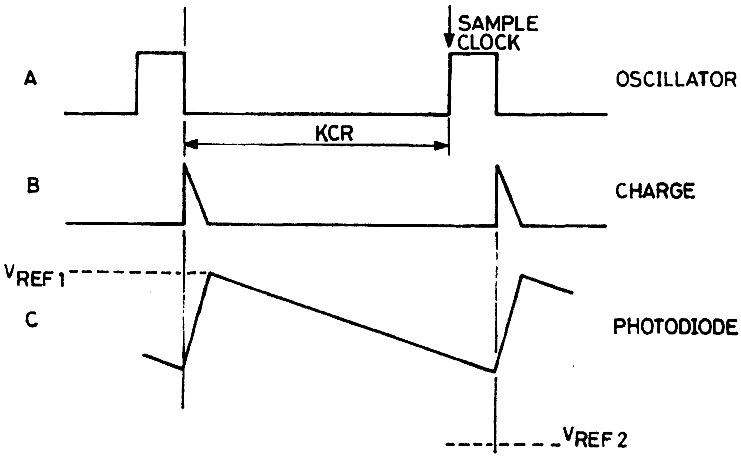
GENERAL OPERATION OF THE PHOTOSWITCH CIRCUIT

The current flowing in the photodiode is made up of a small dark current, which is virtually negligible, and a photocurrent which is proportional to the light intensity on the diode. As the light level changes, the resultant change in photocurrent is measured by monitoring the rate of change of voltage across the photodiode during the discharge of the diode capacitance by the photocurrent. When the light level reaches a predetermined level, the circuit switches. This is achieved as shown in the block diagram and circuit waveforms below.



PHOTOSWITCH BLOCK DIAGRAM

3636/1



WAVEFORMS

3637/1

NOTES

1 The sensitivity is controlled over a wide range by an external RC network.

2 The photodiode is charged to a reference voltage, V_{REF1}, and allowed to discharge with the photocurrent which is defined by the light intensity on the diode.

3 After a time τ_s = KCR, where τ_s is the oscillator space period, the voltage at C is sampled and an output obtained from the comparator (typically K = 0.26).

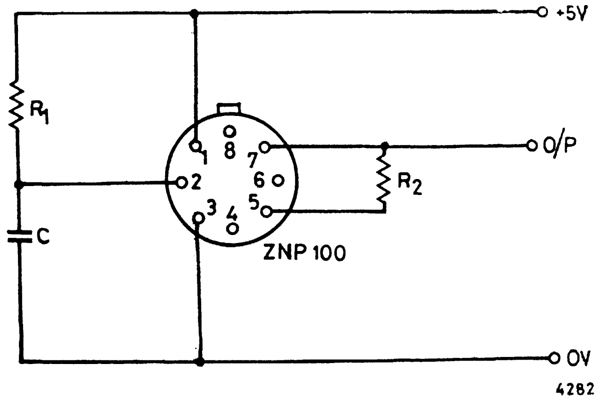
4 This information is staticised by the output bistable, the state of which is dependent on the voltage at C at the sampling time.

5 Hysteresis is provided by an external of internal feedback resistor between output 1 and internal reference V_{REF2}.

ZNP100 Series

GENERAL OPERATION

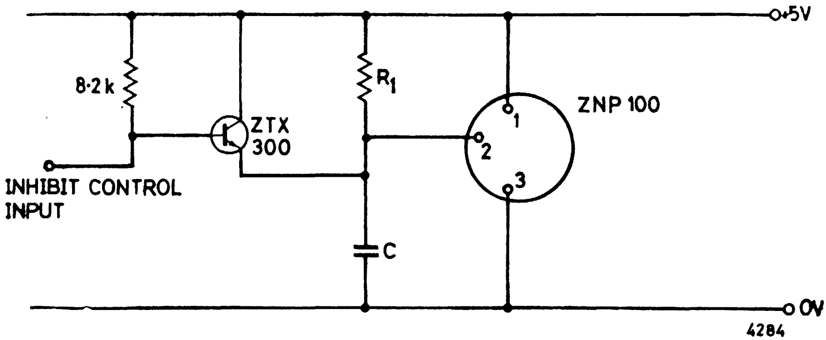
The ZNP100 can be used in two basic modes. The first is self-oscillating where an external resistor and capacitor determine the frequency of oscillation and hence the sensitivity of the device. The second method is to use an external oscillator to set the device sensitivity.



Used in the circuit above the ZNP100 provides a simple light operated switch where R_1 and C are the frequency determining components of an internal oscillator which controls two parameters of the device. Firstly, as can be seen from the sensitivity control graph, R_1 and C are chosen to provide the required sensitivity. However, the frequency of oscillation also controls the maximum switching frequency of the device and if the light variations are not related to the internal oscillator the maximum switching frequency will be, at worst, a quarter of the oscillator frequency. If the light variations are locked to the internal oscillator the maximum switching frequency will be half of the oscillator frequency. The oscillator frequency is given approximaely by $\frac{3.5}{CR_1}$ and so when high switching frequencies are required the light levels used must be high so that CR_1 may be kept small.

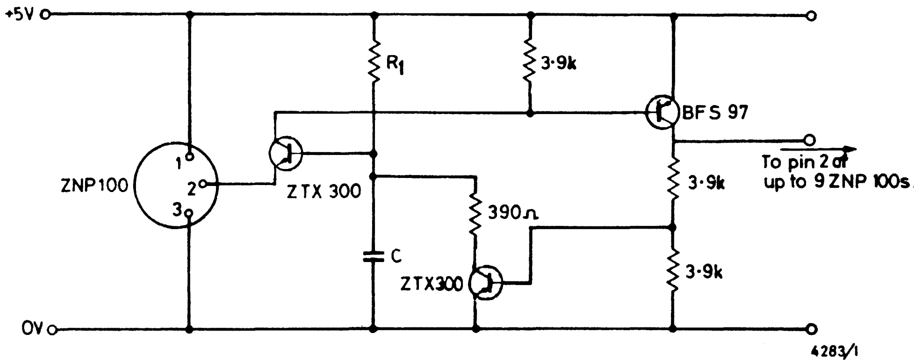
The second resistor on the diagram pre-sets the desired Hysteresis of the ZNP100. A graph is given relating hysteresis to this feedback resistor where the hysteresis is expressed as a percentage given by $\left(\frac{P_{ON} - P_{OFF}}{P_{ON}}\right) \times 100\%$, where P_{ON} and P_{OFF} are light levels at which the device switches on and off. For instance, if the design factor is such that once the device turns on, the light level must be reduced by 10% before it turns off, then the graph will give the value of the feedback resistor required as 80 kΩ. The ZNP102/3 photoswitches have their hysteresis fixed internally to approximately 15% and so do not require an extra resistor.

In some applications it may be desired to hold the present output of the photoswitch regardless of light variations, and this may be achieved using the inhibit circuit shown on page 23.



When the inhibit input is at 0V the transistor will have its base-emitter junction reverse biased and so it will not conduct and thus allows the ZNP100 to oscillate normally. However when the input is taken high the transistor will 'turn-on' and this will cause the photoswitch to cease oscillating and so hold its last output. Just like the ZNP100 outputs, the inhibit control input is TTL compatible.

When an application demands the use of many photoswitches operated at the same sensitivity, it is more practical to use a master oscillator to drive all the inputs of the devices than to use a separate RC network for each photoswitch. The circuit of a master oscillator using a ZNP100 is shown below.



Typical applications of the ZNP100 in self oscillating mode include, *(a)* computer tape reading systems, where their TTL compatible outputs, high switching frequency, small physical size and need for only the extra components of a master oscillator, makes them easy to use, *(b)* detection or counting systems where their high sensitivity makes them especially useful for the detection of the low levels associated with reflected light, *(c)* light level control where the hysteresis can be adjusted to allow the device to ignore the light it is switching on.

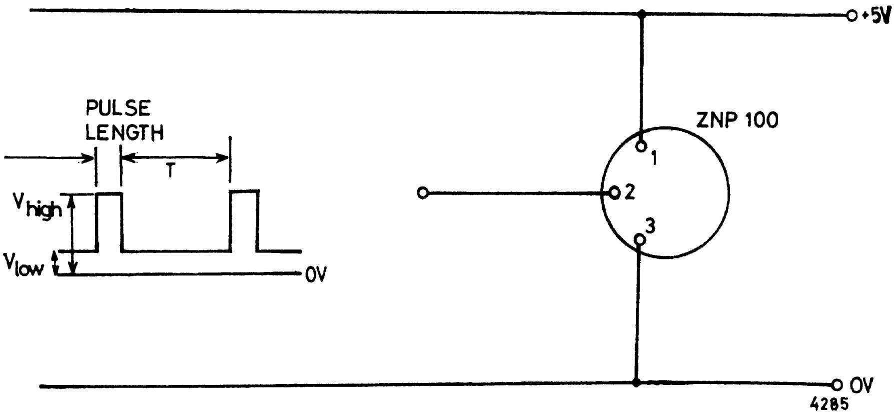
EXTERNALLY DRIVEN MODE

For certain applications it is adventageous to operate the photoswitch from an external pulse generator. External pulse generators are useful when many photoswitches are used at the same sensitivity as mentioned previously, or when it is desired to vary the sensitivity of the photoswitch remotely – which is achieved simply by varying the period between pulses. The necessary drive requirements of the ZNP100 series are summarised in a table on page 24.

ZNP100 Series

Input Pulse Conditions	Min.	Typ.	Max.	Test Conditions
V_{LOW}	0	—	1V	$V_{CC} = 5V$
V_{HIGH}	2.5	—	5	$V_{CC} = 5V$
Pulse length	1 μs	—	—	$V_{CC} = 5V$
Propagation delay*	—	500 ns	—	$V_{CC} = 5V$
Input current	—	16.6	20 mA	Input level = 5V
	—	—	8 mA	Input level = 2.5V

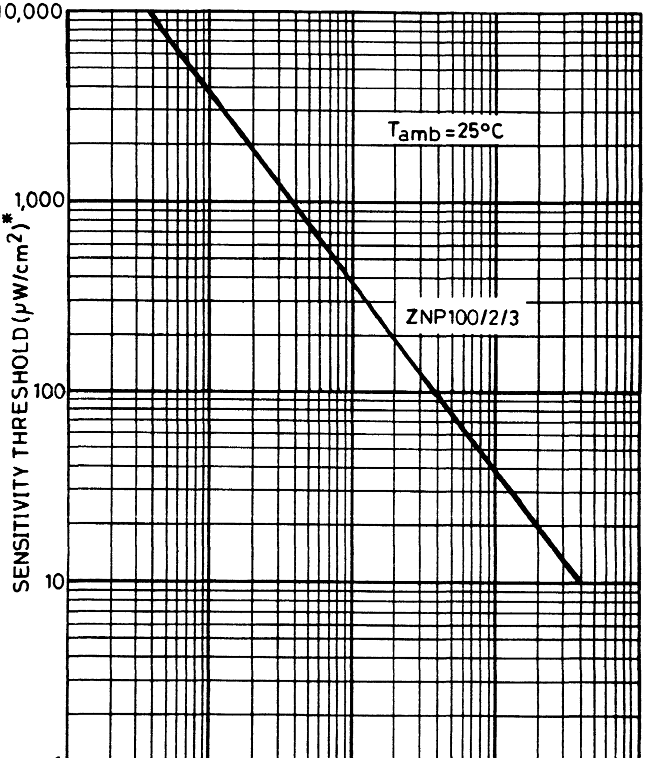
*Propagation delay is the time from the beginning of the input pulse to a change of output level.



The period between input pulses, 'T', required for a given sensitivity can be found by using the relationship $T = 0.26\ CR_1$, where the value of CR_1 is obtained from the sensitivity graph.

TYPICAL SENSITIVITY CONTROL

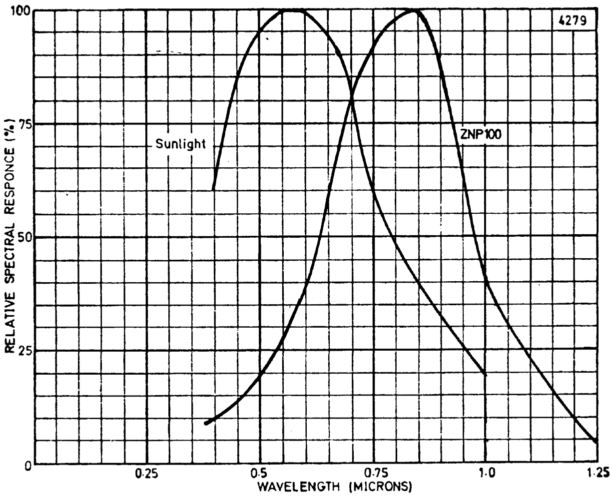
The switching light level threshold can be varied over a wide range by means of an external RC time constant. The graph below indicates typical values:



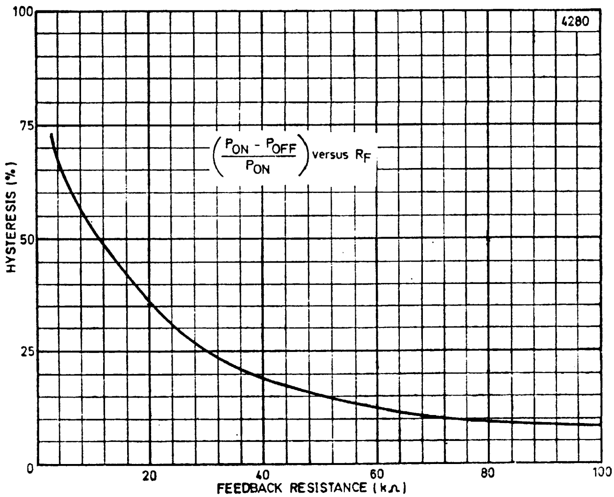
*Illumination: Tungsten light source – Colour temperature: 2856°K

ZNP100 Series

ZNP100 – TYPICAL SPECTRAL RESPONSE

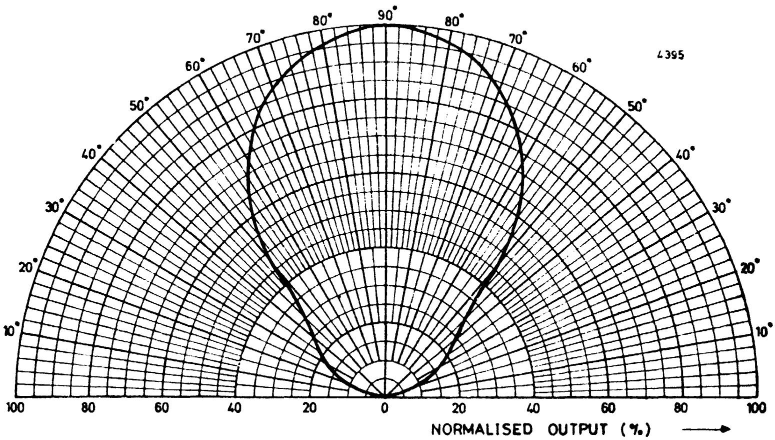


ZNP100 – TYPICAL PLOT OF HYSTERESIS AGAINST FEEDBACK RESISTOR



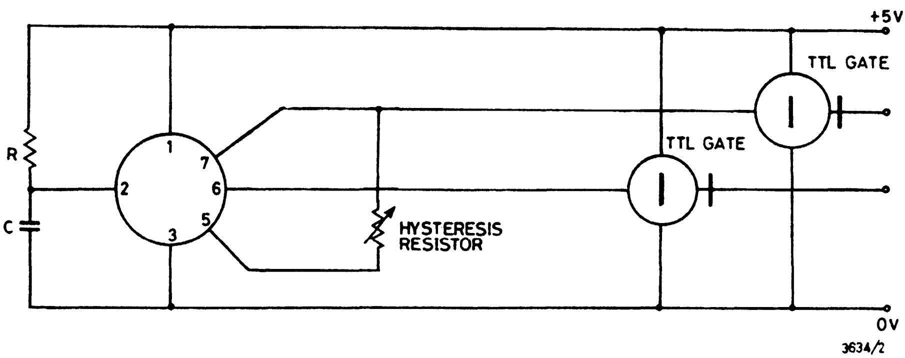
The hysteresis is fixed at 15% on both the ZNP102/3 and ZNP108/9 types.

ZNP102/3 – NORMALISED POLAR RESPONSE



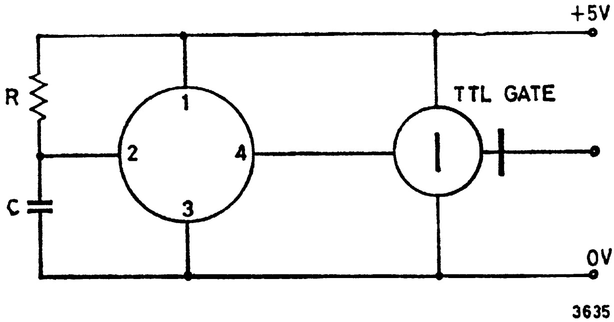
INTERFACING WITH STANDARD TTL

(a) 8 Lead device driving TTL gates.



ZNP100 Series

(b) 4 Lead device driving a TTL gate.



PACKAGE OPTIONS

ZNP100, 8-Lead TO-5

+5 volts
0 volts
Sensitivity Control (External RC Network)
Variable Hysteresis (External Resistor connected between pins 5 and 7)
Output 1 (High when illuminated)
Output 2 (Low when illuminated)

ZNP102, 4-Lead TO-72

+5 volts
0 volts
Sensitivity Control (External RC Network)
Output (Low when illuminated)

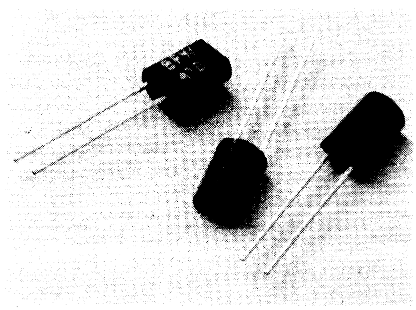
ZNP103, 4-Lead TO-72

+5 volts
0 volts
Sensitivity Control (External RC Network)
Output (High when illuminated)

BPW41D

INFRA-RED PHOTODETECTOR

The BPW41D is a large area, silicon p.i.n. photodiode having a low junction capacitance and consequently capable of fast response times. The active chip is packaged in a plastic moulding which contains a near infra-red transmissive filter such that the device is sensitive to infra-red radiation only, and has a high rejection of wavelengths below 800 nm. The BPW41D is therefore eminently suitable for use in I.R. remote control links.



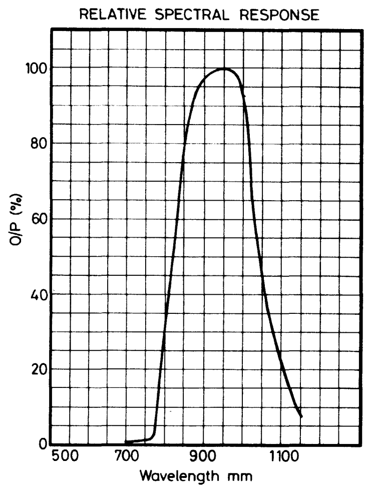
I.R. REMOTE CONTROL APPLICATIONS ADVICE

Advice is available on complete I.R. remote control systems for applications such as those listed below. The combination of I.R. emitting diode, photo-detector and detector electronics is critical in defining the performance of a remote control system, and advice is freely available as to the best system combination for a given application.

SUITABLE APPLICATIONS FOR I.R. REMOTE CONTROL

Television, Hi-Fi Systems, Slide Projectors, Model Cars, Trains, etc., Garage Doors, Domestic Appliances.

(See inside front cover for spectral response).



RELATIVE SPECTRAL RESPONSE

BPW41D

ABSOLUTE MAXIMUM RATINGS (at 25°C ambient temperature unless otherwise stated).

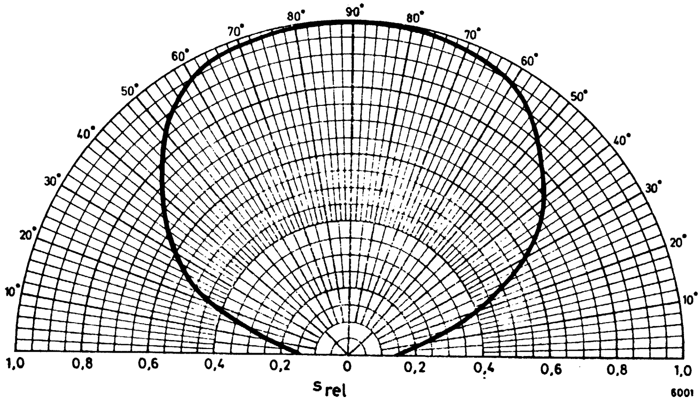
Parameter	Symbol	Value	Unit
Reverse Voltage	V_R	32	Volts
Power Dissipation	P_{tot}	150	mW
Storage Temperature Range		–30 to +80	°C
Maximum Lead Soldering Temperature (⩾2 mm from case for ⩽3 seconds)		245	°C
Typical Wavelength of Peak Response		925	nm
Typical Range of Spectral Bandwidth (Between 50% levels)		820 to 1040	nm

CHARACTERISTICS (at 25°C ambient temperature).

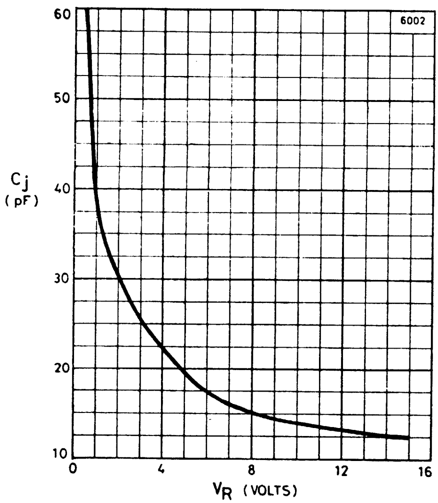
Photovoltaic Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Open-circuit voltage	V_{oc}	—	400	—	mV	$E_v = 1000$ lux (See note 1)
Short-circuit current	I_{sc}	—	70	—	μA	$E_v = 1000$ lux, $R_L = 100\Omega$
		—	43	—	μA	$E_e = 1$ mW/cm^2, $\lambda p = 950$ nm, $R_L = 100\Omega$ (See note 2)
Absolute sensitivity	S	—	50	—	nA/lux	
Junction capacitance	C_j	—	75	—	pF	$V_R = 0$, f = 1 MHz, E = 0

TYPICAL CHARACTERISTICS



POLAR RESPONSE



CAPACITANCE Vs REVERSE VOLTAGE

BPW41D Application Note

Infra-red Remote Control and Data Transmission

INFRA-RED REMOTE CONTROL AND DATA TRANSMISSION

The use of short range remote control and data transmission systems in both consumer and industrial products is growing rapidly. Already common-place in items such as Televisions, Teletext and Viewdata controllers, toy model control etc, these systems are now being used for the remote control of High Fidelity Units, Garage Doors, Light Dimmers, Slide Projectors, and in Teaching Aids, Data links, Burglar alarms etc.

In the past, short range remote control systems have mainly relied on Radio or Ultrasonic links to effect control. However, these methods have serious disadvantages. Radio links require licensing, they often give excessive range and are prone to electrical interference. Ultrasonic links suffer from multipath interface which limits their useable data range and interference from numerous everyday objects that produce sound at ultrasonic frequencies such as keys, coins, bells, electrical apparatus etc. Infra-Red light links can be used for short range remote control and their freedom from many of these problems, in part, explains their rapidly growing popularity.

Generally Infra-Red links consist of a modulation source driving a light emitting diode that radiates at a wavelength of 850 to 970nm. This light is detected by a photodiode and the resulting signal is amplified and decoded to recover the transmitted information. Since I.R. light is used, licensing is not required; the radiation is easily confined to a single room since walls and doors block these wavelengths, and electrical interference is easily rejected. Also multipath interference does not significantly degrade the signal, and there are few domestic light sources emitting I.R. that flicker at a frequency high enough to corrupt a modulated signal.

The main limitations of an optical system result from the low power output available from light emitting diodes combined with noise generated in the photodiode by current flowing in the device due to ambient lighting and leakage. These factors control the operational range of a system and the ambient light levels it can tolerate. The transmitted power can effectively be increased by using lenses to concentrate its light output but this narrows the transmission beam width making alignment too critical for some applications. The receiver signal to noise ratio can be optimised by using a very low leakage, high sensitivity photodiode in conjunction with an optical filter which only passes wavelengths emitted by I.R. light emitting diodes.

The Ferranti BPW41D photodiode has been developed specificlly for use in Infra-Red links. It is a high speed, low capacitance device enclosed in a package which acts as a highly selective I.R. pass filter.

INFRA-RED PHOTODIODES

Photodiodes such as the Ferranti BPW41D, are low leakage silicon p.i.n. devices of planar construction with an active area of 7.5mm^2. The device has a silicon nitride layer over the chip which acts both as a passivating and an efficient anti-reflection coating. The plastic housing of the BPW41D contains a dye which transmits well in the near infra-red part of the spectrum (800nm – 1100nm) but which strongly absorbs visible light (400nm – 700nm). The insensitivity of the device to visible light and its response to infra-red radiation are aided by the silicon spectral response which is low in the blue-green regions and high in the infra-red.

Planar construction is used to keep the reverse leakage current low which is important in small signal applications. The p.i.n. structure gives two main advantages. Firstly, capacitance per unit area is lower than that of a conventional p.n. diode, leading to higher speed of response, and, secondly, the minority carrier lifetime is, in general, higher than in heavily doped silicon giving somewhat greater infra-red sensitivity.

BPW41D

CHARACTERISTICS (at 25°C ambient temperature).

Photovoltaic Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Open-circuit voltage	V_{OC}	—	400	—	mV	$E_V = 1000$ lux (See note 1)
Short-circuit current	I_{SC}	—	70	—	μA	$E_V = 1000$ lux $R_L = 100\Omega$
		—	43	—	μA	$E_e = 1\,mW/cm^2$ $\lambda p = 950\,nm$ $R_L = 100\Omega$ (See note 2)
Absolute sensitivity	S	—	50	—	nA/lux	
Junction capacitance	C_j	—	75	—	pF	$V_R = 0$, $f = 1\,MHz$, $E = 0$

Photoconductive Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Reverse dark current	I_R	—	2	30	nA	$V_R = 10V$, $E = 0$
Light current	I_L	—	75	—	μA	$V_R = 5V$, $E_V = 1000$ lux (See note 1)
		25	45	—	μA	$V_R = 5V$ $E_e = 1\,mW/cm^2$ $\lambda p = 950\,nm$ (See note 2)
Reverse breakdown voltage	V_{BR}	32	—	—	V	$I_R = 100\mu A$, $E = 0$
Junction capacitance	C_j	—	25	40	pF	$V_R = 3V$, $f = 1\,MHz$ $E = 0$
Noise equivalent power	N.E.P.	—	10^{-14}	—	$WHz^{-0.5}$	
Turn-on time	t_{on}	—	50	—	ns	$V_R = 10V$, $R_L = 1\,k\Omega$
Turn-off time	t_{off}	—	50	—	ns	$V_R = 10V$, $R_L = 1\,k\Omega$

Note 1. The Illumination source is Standard Illuminant 'A' (an unfiltered tungsten filament lamp at 2856°K colour temperature).

Note 2. The illumination source is a GaAs l.e.d. emitting at 950nm.

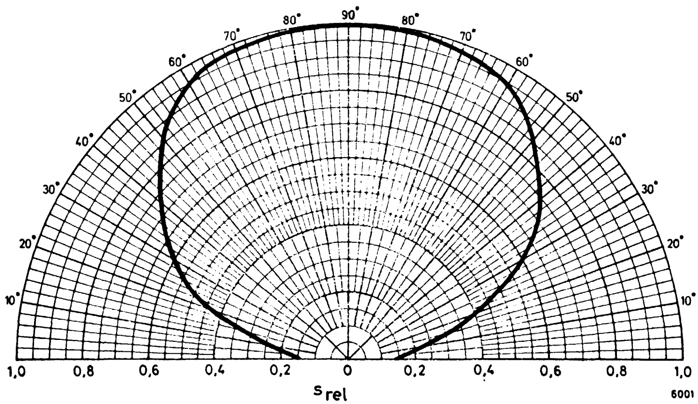
Photoconductive Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Reverse dark current	I_R	—	2	30	nA	$V_R = 10V$, $E = 0$
Light current	I_L	—	75	—	μA	$V_R = 5V$, $E_v = 1000$ lux (See note 1)
		25	45	—	μA	$V_R = 5V$ $E_e = 1$ mW/cm^2 $\lambda p = 950$ nm (See note 2)
Reverse breakdown voltage	V_{BR}	32	—	—	V	$I_R = 100$ μA, $E = 0$
Junction capacitance	C_j	—	25	40	pF	$V_R = 3V$, $f = 1$ MHz $E = 0$
Noise equivalent power	N.E.P.	—	10^{-14}	—	W $Hz^{-0.5}$	
Turn-on time	t_{on}	—	50	—	ns	$V_R = 10V$ $R_L = 1$ kΩ
Turn-off time	t_{off}	—	50	—	ns	$V_R = 10V$ $R_L = 1$ kΩ

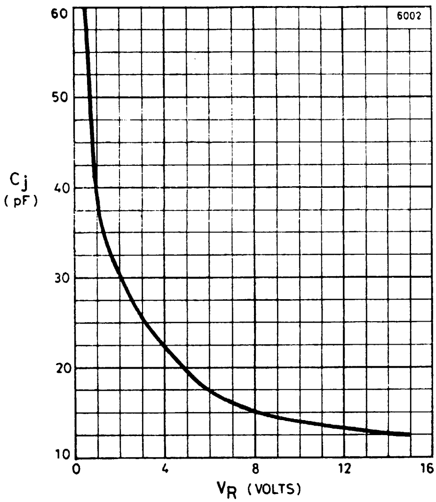
Note 1. The illumination source is Standard Illuminant 'A' (an unfiltered tungsten filament lamp at 2856°K colour temperature).

Note 2. The illumination source is a GaAs l.e.d. emitting at 950 nm.

TYPICAL CHARACTERISTICS



POLAR RESPONSE



CAPACITANCE Vs REVERSE VOLTAGE

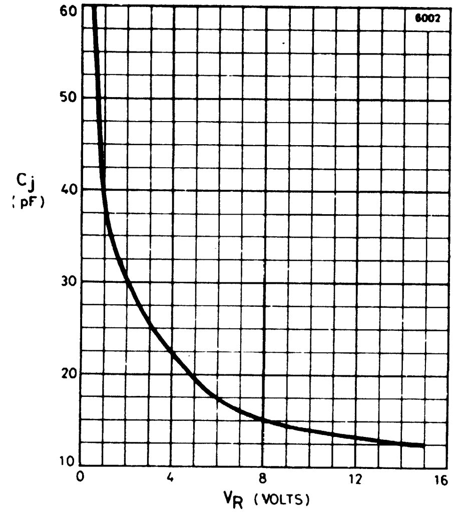


Fig. 1. CAPACITANCE Vs REVERSE VOLTAGE

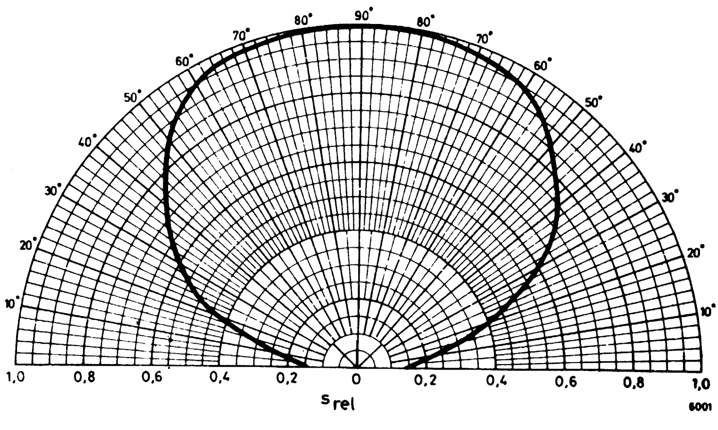


Fig. 2. POLAR RESPONSE

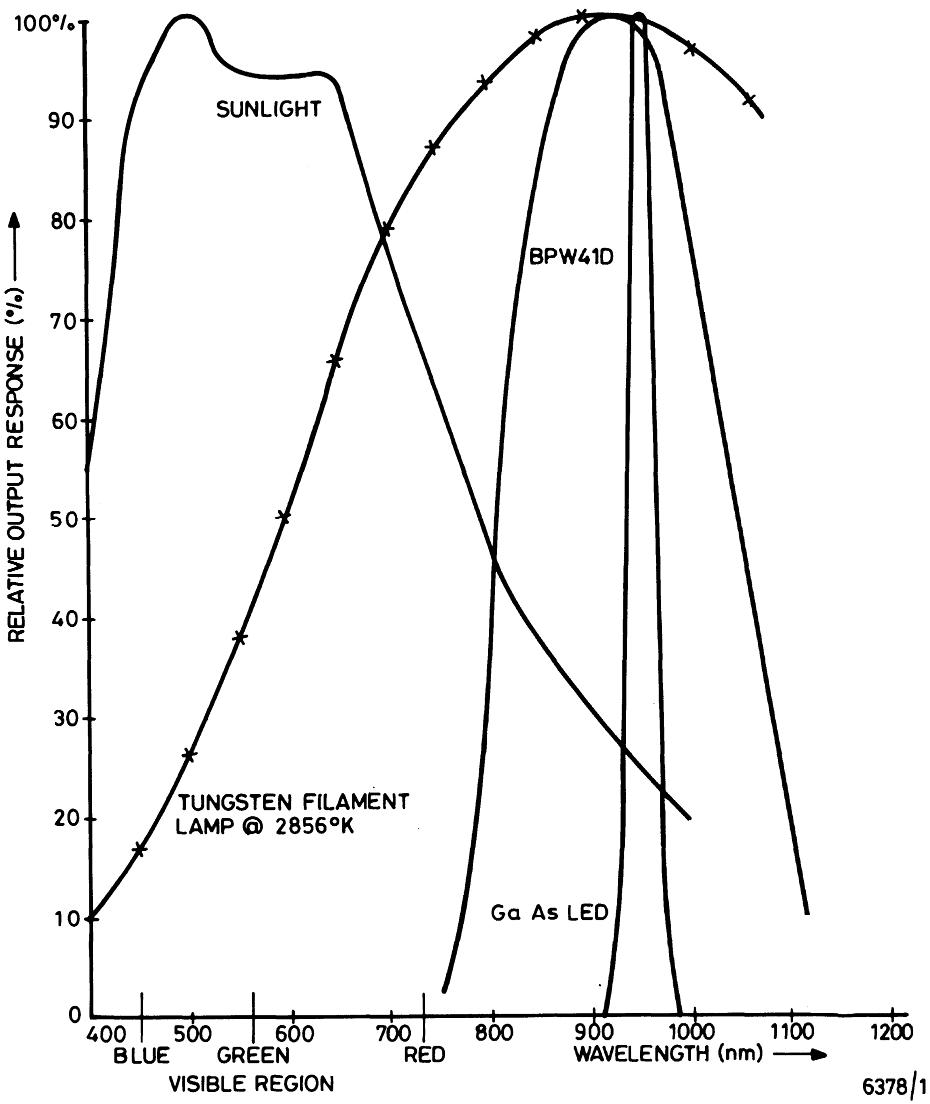


Fig. 3. SPECTRAL RESPONSE OF BPW41D WITH SOME COMMON LIGHT SOURCES

BPW41D Load Circuits

When used in typical remote control links, the BPW41D can provide useable signal to noise ratios with signal levels that can only produce photocurrents of the order of 10nA. However, to detect such levels, the load used for the photodiode must be carefully chosen to suit the particular operation conditions.

Simple Resistive Loads

The simplest load that can be used is a resistor as shown in Fig. 4. In this circuit the photodiode is connected reverse biased across the power supply with a resistor R in series. Any signal current produced by the photodiode will develop a voltage across R which can be amplified to give the required output.

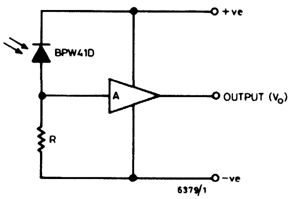


Fig. 4

Assuming $Z_{IN}(A) \gg R$

$$V_O = I_D \times R \times A$$

$$f_C = \frac{1}{2 R C_D}$$

Where I_D = BPW41D signal current
and C_D = BPW41D capacitance

There are various constraints in choosing the value of R. The lower R is made, the smaller the signal voltage appearing across it will be. For a given output voltage this means the gain of amplifier A will have to be higher, making its noise contribution more significant and its interference rejection and stability harder to achieve. As a result, if R is made too small the operating range of the I.R. link is reduced.

With a high impedance amplifier the bandwidth of the circuit will be controlled by the capacitance of the photodiode and the value of R. As R is increased the cut-off frequency falls. Since most I.R. links use short duration light pulses for control, the receiver circuit must have sufficient bandwidth to detect these pulses without significant attenuation. This gives one limitation on the maximum value of R.

A second and possibly more stringent limitation to the maximum value of the load resistor that can be used, is caused by photocurrent in the BPW41D due to ambient lighting. Although the BPW41D includes a selective optical filter to reject light below 700nm, many light sources give a significant proportiion of their energy output above these wavelengths. The effect of these sources on the photodiode is to cause a steady d.c. current to flow through the device developing a voltage across R.

This reduces the reverse bias applied to the photodiode, increasing its capacitance and so reducing the bandwidth. Also if R is much too large, the voltage developed by ambient light photocurrent can exceed the supply voltage, with the photodiode becoming forward biased. In this condition any signal current detected will be dissipated in the forward biased shunt resistance of the photodiode and so the signal output level will be severely attenuated.

As a result of these problems the simple resistor load is mainly used in applications where ambient light levels are low. For instance, it is sometimes used in the remote control of television receivers where its obvious simplicity keeps costs down and its inability of operating efficiently in high light levels is unimportant as the television is unlikely to be operated under such conditions. The values of R typically used in remote control systems range from 100kΩ to 300kΩ giving circuit cut-off frequencies of 30kHz to 100kHz and an ability to handle ambient light levels that cause 30μA to 100μA of photocurrent. This corresponds to a reasonably well lit room using tungsten filament lamps.

The simple resistor load can be modified to handle higher light levels without massive sensitivity loss with the circuit shown in Fig. 5.

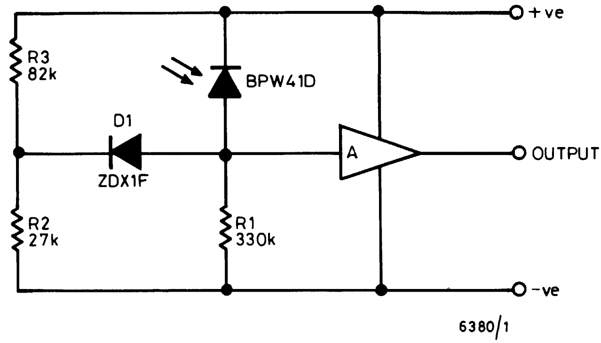


Fig. 5.

At low ambient light levels this circuit will operate with the 330kΩ resistor as the photodiode load, giving a similar sensitivity to the simple load. At high light levels the voltage across the 330kΩ resistor exceeds the voltage set up by the potential divider R_2, R_3. This causes diode D_1 to conduct so that the effective load of the photodiode is the potential divider circuit which has a resistance of approximately 20kΩ. This gives a times 15 loss in sensitivity, but the circuit will continue to work in ambient light levels approaching direct sunlight. If the photodiode is not prevented from becoming forward biased by this, or alternative circuits, the loss in sensitivity at high light levels will be in the order of 1000 times.

Inductive loads

The optimum load for a photocell in a remote control circuit has a high impedance at signal frequencies and a low impedance at any other frequencies including d.c. These load characteristics can be achieved with an inductive load.

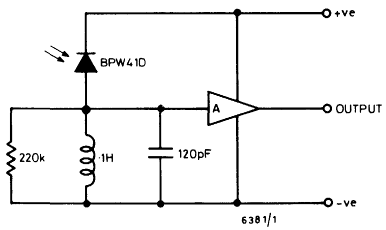


Fig. 6a.

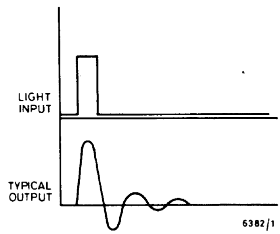


Fig. 6b.

The inductive load shown in Fig. 6a can provide a signal frequency impedance of 100kΩ whilst still giving a very low d.c. current resistance path for photocurrent caused by ambient lighting. As a result, it will operate well over a wide range of ambient light levels. The inductor is normally tuned to match the input frequency and damped with a resistor to suppress ringing.

The output of the circuit when pulsed with I.R. light is shown in Fig. 6b. It consists of a damped sine wave that takes several cycles to decay. Unfortunately this ringing reduces the maximum data rate the circuit will support since delays must be included in the receiver decoder to avoid detecting multiple pulses as the sine wave decays. Some ringing is unavoidable due to the capacitance of the photodiode and other stray effects acting with the indicator load, so that the best solution is to tune the load, match the signal and dampen with a resistor that does not significantly reduce the impedance of the load.

The circuit does have other disadvantages which limit its usefulness. It is difficult to wind the inductor without its natural self capacitance bringing the self resonant frequency below the operational frequency required. To keep its mechanical size small, it is necessary to use a ferrite core to reduce the number of turns in the inductor. However d.c. current flowing in the inductor due to ambient light photocurrent can saturate the ferrite core if the light level is high and the core volume small, so reducing the inductance of the coil and lowering the impedance of the load at signal frequencies. This problem adds further restrictions on the design of the inductor.

The inductor load circuit is used in the remote control of television receivers as an alternative to the simple resistive load. It can give a sensitivity similar to that of the resistive load, has better high ambient light level tolerance but a lower data transmission rate.

Active Loads

The optimum load characteristic of high impedance at high frequencies, yet low impedance at low frequencies and d.c., can be achieved with an active load. Three configurations of the same basic active load circuit but with differing output polarities and output impedances are given in Figs. 7, 8 and 9.

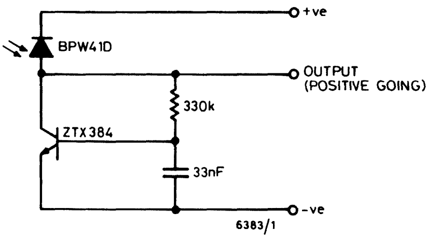


Fig. 7.

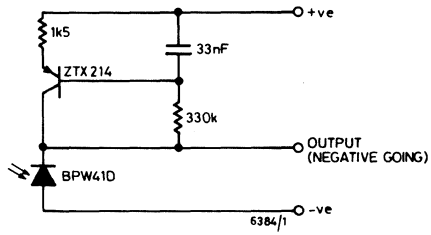


Fig. 8.

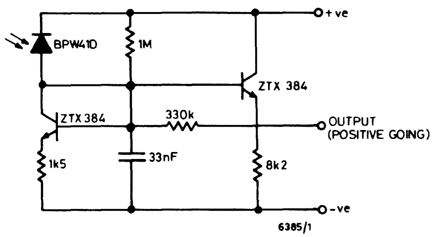


Fig. 9.

Consider the circuit shown in Fig. 7. In this circuit current passed by the BPW41D flows through the 330kΩ resistor to the base of a ZTX384 transistor. This causes the transistor to conduct, shunting the photodiode current directly to the negative supply and so reducing the base drive to the transistor. An equilibrium point is reached in which the transistor holds its collector voltage at approximately 0.8V by acting as a constant current generator that exactly matches current fed to it by the photodiode. This equilibrium is maintained for d.c. or slowly varying photocurrents, so giving the photodiode a very low impedance load under these conditions.

The current dump transistor has a capacitor connected to its base which restricts the speed at which the load circuit can respond to a sudden change in photocurrent. As a result, the current matching equilibrium of the load circuit is not maintained for rapidly changing photocurrents. This makes the high frequency impedance of the load very much higher than its low frequency impedance.

With the component values given, the load presented to the photodiode under steady state conditions is approximately 1 kΩ. At high input frequencies the load impedance is dominated by the base resistor of the transistor and approaches 250 kΩ (at a frequency of 50 kHz).

The high frequency impedance of the load drops slightly under high ambient light levels, but the main disadvantages of the circuit shown in Fig. 7 are its noise contribution and susceptibility to interference at high light levels. Both these problems stem from the extremely high amplification given to any signal generated in the base-emitter circuit of the load transistor under high ambient lighting conditions.

The voltage gain given to a signal generated in the base emitter circuit is approximately:

$$\text{Gain} \approx \frac{R_C}{r_e}$$ where R_C is the collector load impedance i.e. 250 kΩ and r_e is the intrinsic emitter resistance.

$$r_e = \frac{25}{I_e}\ \Omega$$ where I_e is the transistor emitter current (mA)

$$\text{i.e.} \quad \text{Gain} \approx \frac{R_C \times I_e}{25}$$

If ambient lighting causes a photocurrent of 5 μA to flow through the load (current through the photodiode in a dimly lit room).

$$\text{Gain} = \frac{250 \times 10^3 \times 5 \times 10^{-3}}{25} = 50 \text{ For } 5\,\mu\text{A photocurrent}$$

However if the ambient light level approaches direct sunlight

$$\text{Gain} = \frac{250 \times 10^{-3} \times 1}{25} = 10{,}000 \text{ For } 1\,\text{mA photocurrent}$$

This very high amplification given to noise generated in the load transistor degrades the performance of this load circuit when operated at high ambient light levels.

The gain at high photocurrents can be significantly reduced by including a resistor in the emitter of the current dump transistor as shown in Fig. 8. The performance at low light levels is unaffected but the voltage gain given to noise signals in the base emitter circuit of the load is much lower when ambient light levels are high.

$$\text{Gain} = \frac{R_c}{r_e \times R_e} = \frac{250 \times 10^3}{\frac{25}{1} + 1.5 \times 10^3} \approx 160 \text{ For } 1\,\text{mA photocurrent}$$

The added resistor restricts the maximum gain given by the load transistor so limiting the noise and interference introduced by the circuit.

The emitter resistor also increases the impedance of the load at low frequencies and so its value is a compromise between minimum noise contribution and minimum d.c. voltage drop at high photocurrents. The value used in Fig. 8 ensures that the noise generated by the load is less than that of the photodiode, yet the circuit can still operate in direct sunlight.

To take advantage of the high impedance of these load circuits, the amplifier connected across the load must have a high input impedance. If a low impedance amplifier is to be used, an emitter follower buffer can match the photocell load to the amplifier as in Fig. 9. The emitter follower is d.c. coupled to the load to eliminate the coupling and biasing components that otherwise would have been required. It has an output impedance of approximately 2 kΩ at small signal levels.

All three loads may be modified to give signal outputs of opposite polarity simply by exchanging ZTX214 transistors for ZTX384 and vice versa, and reversing the power supply connections and those of the BPW41D.

Remote Control using the BPW41D

It is a vital requirement that remote control circuits cannot be triggered by spurious signals. To achieve this immunity without sacrificing range of operation, coded transmissions are normally used so that only received signals of a pre-determined sequence are allowed to alter control outputs. Effective coding and decoding requires elaborate circuitry if constructed using standard logic devices. However, numerous dedicated integrated circuits have been developed for this task.

Ferranti Infra-Red Transmitter Receiver System

This system provides an economical means of transmitting and receiving up to nine digital codes over a distance of several metres. The system also provides a means of operating two separate systems independently.

The devices are designed to have low current consumption, so that hand held battery operation is possible, and to have maximum resistance to interference from fluorescent lights and/or sunlight.

The circuits were originally designed for remote control of toy cars and therefore the system is very much tailored to a consumer application which is easy to manufacture and offers a repeatable performance.

Transmitter

The inputs are taken from a simple pcb keyboard and, as shown in Fig. 10, are fed into a serial sequencer and code generator. The digital signals are then buffered and fed to the output transistor which drives the infra-red emitting diodes. The diodes are pulsed at approximately 2A for 25μs with a repetition rate which ensures that the maximum power dissipation of the diodes is not exceeded.

The code transmitted consists of 5-bits, one of which is set permanently to define which transmitter/receiver system is to be activated.

To simplify the decoding, codes with 111 and 000 are not used. In a 14-lead package 9 codes can be accommodated.

The output consists of a series of six pulses separated by a space. The code is defined as follows:

1.6ms between pulses represents a '1'
2.4ms between pulses represents a '0'
4.8ms between pulses represents a space

Although the transmitter/receiver combinations have an identifier bit to ensure that one system cannot work from the other, a problem could arise when both transmitters are operating, i.e. the receivers would detect a somewhat confused signal. Therefore, to ensure that clear signals are received, the transmitters have different output rates. One system transmits three bursts of the output codes followed by a gap of four word lengths whilst the other system transmits six bursts of the output code followed by a gap of eight word lengths.

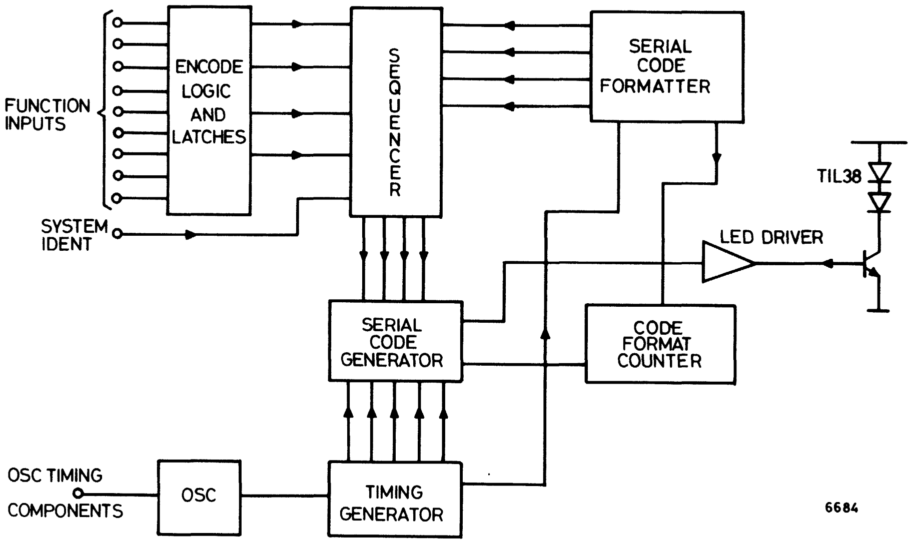


Fig. 10. Transmitter Block Diagram

Receiver

The signals from the infra-red emitting diode are detected by a BPW41D photodiode. These signals are then amplified and fed to a pulse length detector which generates the output. This is stored in a latch until another code burst is detected. When two consecutive code bursts are identical the latch information is decoded and fed to the output circuitry. The restriction on the clocks used in the system is that there can be a 50% error margin between the transmitter and receiver clocks before the system will fail to operate. This tolerance is therefore easily achieved with standard components.

As shown in Fig. 11 a facility exists for ensuring that in the original application, the car would have the facility to resume a straight course after it had been knocked off-course by hitting an object in its path. The system would drive back to the centre position where contacts indicate the centre position. The system will then 'home' in on the centre position.

For a complete system the transmitter requires 3 capacitors, 3 resistors, one ZTX450 and the I.R. emitting diodes. the circuit is based on a digi-lin VLP array and takes typically 2/3mA current in the standby mode and is available in a 14-lead package.

The receiver requires 7 capacitors, 9 resistors, 1 preset resistor, one transistor for the series regulator (ZTX108), the output drive transistors (2ZTX450 + 2ZTX550), and the BPW41D photodiode. The receiver is based on a Low Power RTL array and the current consumption is typically 15mA. The circuit is available in a 24-lead package, two of which are not connected.

Coder/decoder chips are used here together with the BPW41D photodiode in a remote control link intended for use in television receivers. The system has a maximum range of 15m.

Although intended for television control, the remote contol link may be used for a variety of applications simply by modifying the output circuitry. To facilitate this it has been designed to operate at high ambient light levels if necessary. The encoder/decoder set used provides the logic to control the selection of up to ten pre-tuned channels, adjust three analogue controls, and also switch the controlled unit on and off.

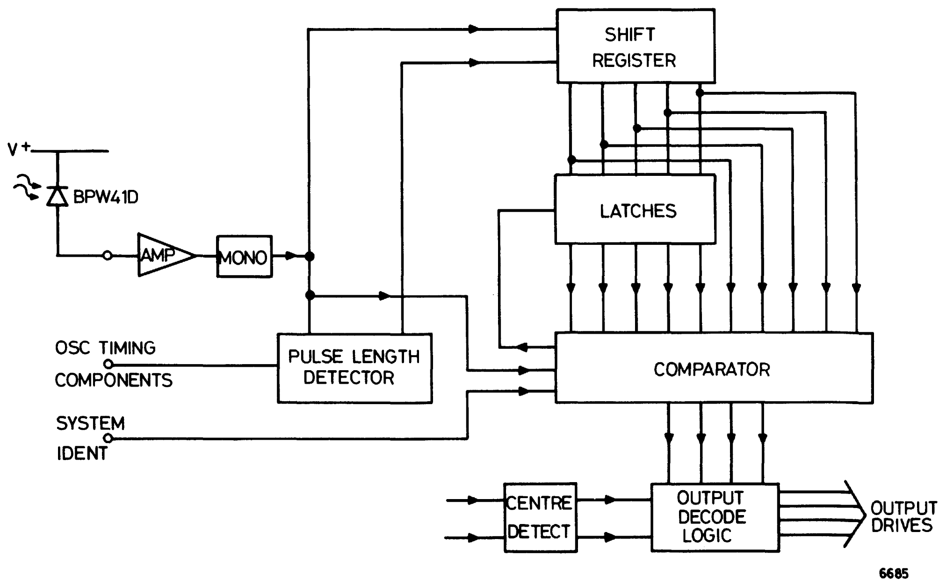


Fig. 11. Receiver Block Diagram

Transmitter (Fig. 12)

The transmitter makes use of an encoder which reads a matrix connected keyboard and, on finding a key pressed, generates a corresponding pulse string. The integrated circuit codes this pulse string by varying the period between six fixed length output pulses. The pulse string is repeated continuously until the key is released, at a rate controlled by R1 and C2. The output of the coder which appears on Pin 3 of the device is fed through a differentiating circuit that limits the pulse width to 15µs.

The shortened pulses are buffered by a ZTX650 transistor and then used to drive two infra-red light emitting diodes. As the I-R diodes are only illuminated for 15µs in every 25ms it is permissable to pass a higher current through the devices than their continuous ratings allow. This circuit passes a 2A peak through the emitters to maximise range, yet the low duty cycle allows the use of inexpensive output diodes and gives the circuit low operational current drain.

The quiescent power supply current taken by the transmitter is approximately 2µA (maximum of 30µA), rising to 15mA when a key is pressed. As the quiescent current is so low, no on/off switch is required for the circuit. The power for the transmitter is taken from a 9V radio battery which, under normal use, should give a life of one year.

The construction of the transmitter circuit is not critical except for the wiring of the high current loop consisting of C4, the ZTX650 transistor and the light emitting diodes. The wiring of this loop should be kept short to minimise its resistance and inductance.

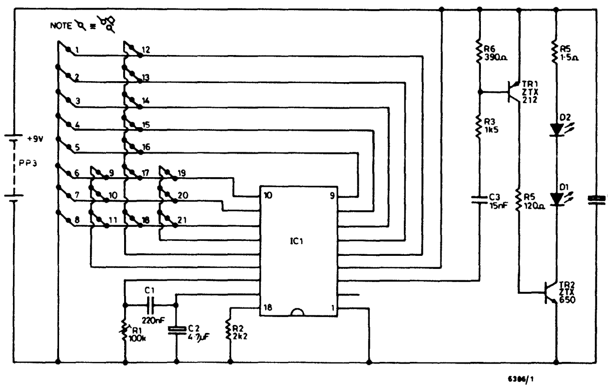


Fig. 12. Remote Control Transmitter Unit

Remote Control Receiver Circuit (Fig. 14)

The BPW41D photodiode is used to detect infra-red pulses emitted by the transmitter. An active load is used with the photodiode to ensure operation over a wide range of ambient light levels. The signal developed across the load is fed to a low noise high input impedance amplifier circuit which increases its amplitude to a useable level.

The output of the amplifier during reception consists of negative-going pulses of short duration superimposed on background noise. The coded signal is separated from noise and interference by a peak detector with a long recovery time.

This makes the detector sensitive to the highest peaks of a given signal only. The detector output is only lightly loaded so that the recovery signal amplitude is limited by the supply voltage.

Key No	Code Generated	Receiver Function	Key No	Code Generated	Receiver Function
1	00000	Channel 1	12	00010	Channel 2
2	00100	" 3	13	00110	" 4
3	01000	" 5	14	01010	" 6
4	01100	" 7	15	01110	" 8
5	10000	" 9	16	10010	" 10
6	10100	Analogue 1 +	17	10110	Analogue 2 +
7	11000	Supply Off	18	11110	Analogue 2 −
8	11100	Analogue 1 −	19	10111	Analogue 3 +
9	10101	Step Channel No +	20	11011	Normalise
10	11001	Toggle O/P (AN 2)	21	11111	Analogue 3 −
11	11101	Step Channel No −			

Fig. 13. Key Function Table

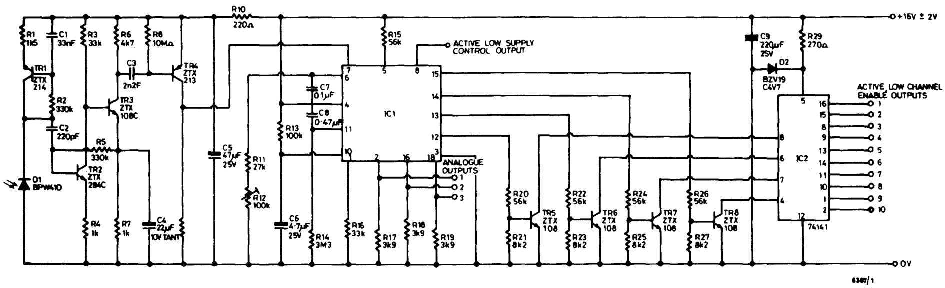


Fig. 14. Remote Control Receiver unit Part 1

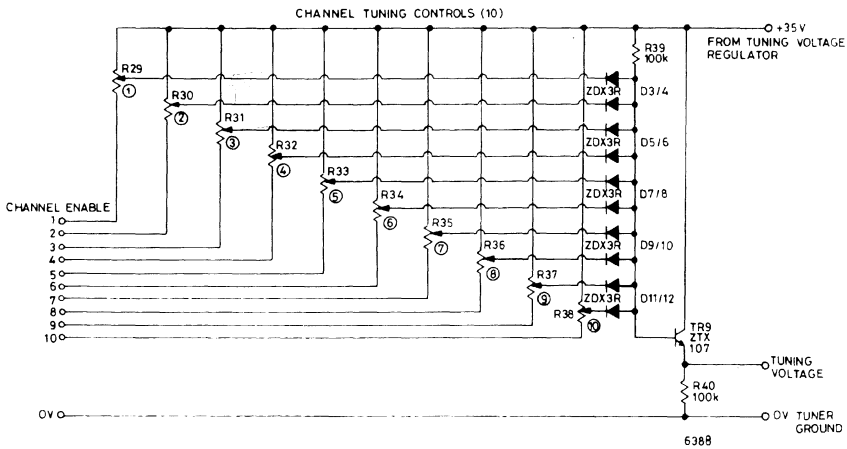


Fig. 15. Remote Control Receiver unit Part 2

The limited signal is fed to a decoder which checks that format is correct. If two consecutive identical pulse strings are received, which are correctly formatted, the decoder will obey the command given. This elaborate check ensures that only valid commands are acted upon.

To control a television receiver the decoder provides three groups of outputs. The first group, comprising of pins 12, 13, 14 and 15, gives the four-bit B.C.D. value of the channel number selected. These outputs are inverted and level shifted to drive a decoder which will select the desired television channel on a varicap tuner. Fig. 13 shows a a temperature compensated circuit that can be used to interface the B.C.D. decoder to the tuner of the television.

The second group of outputs provide three analogue controls. Appearing on pins 2, 16 and 18, they take the form of a voltage which may be varied from zero to 5V in 32 discrete steps. These outputs are normalised which on switch-on or by command key 20, to half their full-scale output.

If the remote control decoder has a power supply independent of the television receiver, the system may be used to turn the set on and off. The output on pin 8 is initialised to $+V_{DD}$ on turn-on. When the first channel select or analogue adjust command is programmed, this output falls to 0V until an "off" command (key 7) is received. Thus this output may be used to control the mains supply to the television receiver.

The receiver construction is more critical than that of the transmitter in some areas. The active load and low noise amplifier should be carefully sited to minimise output-to-input coupling which can cause instabilities due to the very high gain of these stages. The circuit should be mounted with the photodiode in a screened box which includes a small hole for light entry to the BPW41D. The receiver circuitry consumes approximately 50mA and its power supply should be well smoothed.

Initial Setting Up

The transmitter data rate control R1 should be adjusted so that the minimum period between light pulses is in the range of 10ms to 50ms. This can be checked using an oscilloscope to observe the collector voltage of the transmitter output transistor TR2 during a key press (not key 1).

The receiver data rate control R_{12} should be adjusted so that the period of the signal on pin 6 of the decoder is $\frac{1}{27}$ times the minimum period set up on the transmitter. Alternatively R12 may be varied slowly, whilst operating the transmitter, noting the adjustment range of R12 for which the receiver successfully detects codes, then setting the data rate control to the middle of this band.

If it is desired to use more than one infra-red link in the same area, selectivity between links may be achieved using the data rate controls. The receiver of one link will not react to the transmitter for another link if the setting of the respective data rate controls differ by more than 30%

Warning

If this remote control link is fitted as a modification to a television receiver it must be remembered that most sets have a live chassis, i.e. it is possible that the chassis is normally at mains supply potential. The control receiver should therefore be constructed so that it is impossible to contact any metal parts on the chassis once it is connected to the television receiver.

MONOPHONIC AUDIO LINK (M.A.L)

A infra-red link capable of transferring audio signals has been constructed using the BPW41D photodiode as the receiving element. The link was designed to allow the use of monophonic headphones with a television or music centre without the inconvenience of trailing leads. It uses a frequency modulated system to ensure that volume levels are independent of range. Depending on the ambient light levels and reflectivity of room walls, the link gives satisfactory performance up to a range of 8m. Its frequency response is from 50Hz to 8kHz.

M.A.L. Transmitter (Fig. 16)

The audio signal to be transmitted is fed through a gain control R1 to an audio amplifier which gives the circuit an input sensitivity of 100mV RMS. As part of a noise reduction system the audio amplifier boosts signals at high frequencies by applying 55μs pre-emphasis.

The output of the audio amplifier is capacitively coupled to two constant current generators, these being used to charge the timing capacitors of a multivibrator. Consequently, the generators control the oscillation frequency of the multivibrator. Since the constant current generators are controlled by the audio amplifier output, the multivibrator is frequency modulated by the audio input. The multivibrator runs at a central frequency of approximately 70kHz and with a mark space ratio of 1 to 1. The emitter circuit of one of the multivibrator transistors includes a ZTX650 transistor.

The ZTX650 transistor is used as a buffer to provide the high current drive necessary for the infra-red light emitting diodes. Six emitters wired in two groups of three provide the modulated light output, their peak drive current being limited to 300mA.

It is possible for simple multivibrators to attain a latch-up state in which both transistors conduct continuously in saturation, giving a loop gain too low for oscillation. In this circuit the supply for the constant current generators which bias the multivibrator transistors is derived from the collector loads of the multivibrator. As a result, if latch-up should occur, the base drive for the multivibrator will decay, bringing the transistors out of saturation, so raising the loop gain and enabling normal oscillation to occur.

The supply for the current generators is regulated by a zener diode to minimise the frequency variations resulting from power supply voltage fluctuations. The regulating zener also has the effect of restricting the multivibrator collector voltage swing to approximately 6V. This prevents the charge on the timing capacitors reaching V_{BE} breakdown levels and subsequent damage of the emitter-base junctions of the multivibrator transistors. The supply for the audio amplifier is also taken from this regulator to restrict its output swing to that required by the current generators. Construction of the transmitter is not critical.

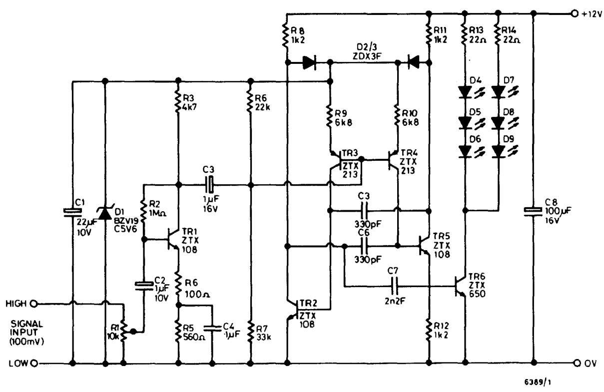


Fig. 16. M.A.L. Transmitter Unit

M.A.L. Receiver (Fig. 17)

The receiver uses a BPW41D photodiode to detect the infra-red signal emitted by the transmitter. The photodiode has an active load which reduces the effects of ambient lighting. The signal voltage appearing across the load is coupled into a very high gain amplifier which boosts it to a suitable level for F.M. demodulation.

Frequency demodulation is achieved using a standard CMOS phase locked loop logic device. The output of the amplifier is a.c. coupled into a self biasing Schmitt Trigger input in the phase locked loop. The signal is compared with an internal voltage controlled oscillator by a phase comparator which produces an error voltage that is dependent on the phase difference. This error signal is used to adjust the frequency of the voltage controlled oscillator so that it is locked or made identical to the incoming signal frequency. When this locking is achieved, the voltage output of the phase comparator is proportional to the incoming signal frequency and so reproduces the audio signal fed into the transmitter.

The output of the phase detector is fed through a de-emphasis network which has a time constant of 55μs. This has the effect of reducing the noise and signal amplitudes at high frequencies since the signal at the transmitter was boosted by an identical network. The pre-emphasis and de-emphasis gives a flat link frequency response whilst significantly reducing receiver noise.

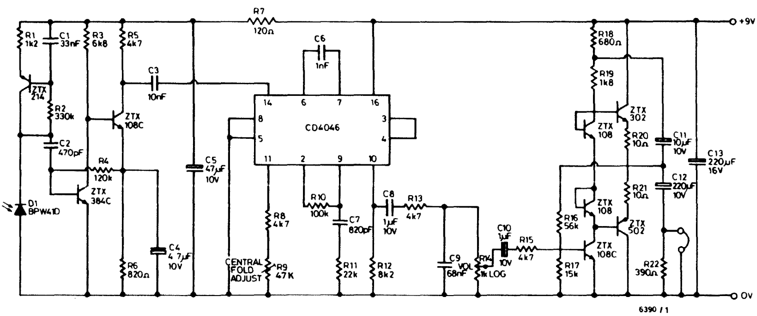


Fig. 17. M.A.L. Receiver Circuit

The corrected audio signal is then fed to an audio amplifier via a volume control.

The audio amplifier is intended to drive headphones with an impedance of 4Ω to 16Ω. It has a complementary push-pull output stage which employs a temperature compensated biasing circuit.

The receiver active load and amplifier circuits should be carefully laid out to minimise output to input feedback paths otherwise instability will occur. The receiver should also be mounted in a metal case with a hole cut for light entry to the BPW41D.

M.A.L. Setting Up

The receiver phase locked loop centre frequency can be adjusted to the transmitter output frequency either by using an oscilloscope and comparing the latter to the frequency on the receiver diode pin 4 or by feeding a low level audio signal into the transmitter, gradually covering the photodiode with an opaque material and adjusting the centre frequency control for best signal recovery. Once this adjustment has been made the transmitter input level control should be set to give the maximum audio signal output before distortion due to overloading occurs.

BEAM INTERRUPTION DETECTORS (B.I.D.)

Beam interruption detectors have a variety of uses ranging from object counting to burglar and fire detection alarms. They generally consist of a transmitter that emits a beam of light to a detector. Should this beam be broken, the detector gives a change in output level, The detector must discriminate between the transmitted beam and other light sources and this can be achieved by using a lensed system to make the detector directionally selective, or by modulating the transmitter output and then making the detector select only correctly modulated sources. The lensed system uses simple transmitter and detector circuitry but mechanical construction and installation alignment are necessarily critical. The modulated system has the advantage of being easier to set up, but requires more complicated transmitter and detector circuitry.

A beam interruption detector using the BPW41D photodiode in a modulated system has been developed. It includes a transmitter circuit and a choice between two detector circuits of differing range capability. All the circuits are powered from a 5V d.c. supply to facilitate their operation with standard integrated circuit logic devices.

B.I.D. Transmitter

The transmitter consists of an oscillator which drives a high output infra-red emitting diode. The oscillator is a sure-start multivibrator circuit which provides an output of 15 to 1000 mark-space ratio at a frequency of 1 kHz. This large mark-space ratio allows the infra-red diode to be operated at a high peak current so as to maximise the range of the link. A decoupling network is included in the power supply of the transmitter to isolate it from any logic circuitry using the same 5V power source. The transmitter supply current is approximately 65 mA.

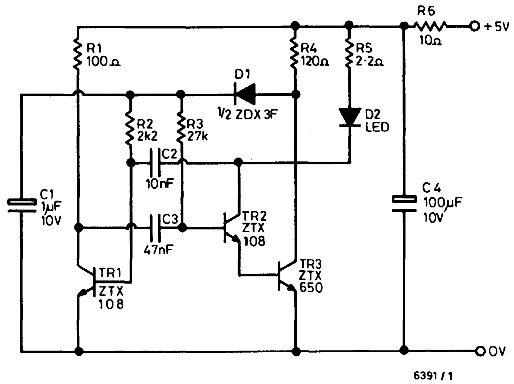


Fig. 18. B.I.D. Transmitter Circuit

Beam Interruption Short Range Detector

The short range detector circuit shown in Fig. 18 is intended for use in parts counting and similar applications. A BPW41D photodiode with a simple resistor load is used to detect the transmitted beam. An active load is not used because it is usually easy to screen out interfering light sources in short range systems. The output of the photodiode is coupled to a single stage high input impedance amplifier which drives a pulse detector. The output of the pulse detector is low whilst a sufficiently strong transmitter beam is received and high once this beam is interrupted.

The maximum range from the transmitter over which this detector will operate is approximately 0.7m. If necessary this can be increased by using a small lens with the transmitter L.E.D. to effectively increase its output. Using a 16mm dia. lens of 10mm focal length, the range using this detector was increased to 6m. It should be remembered, however, that using a lens on the transmitter will make its alignment more critical.

The construction of this detector is not too critical, but electrical screening may be necessary in industrial environments.

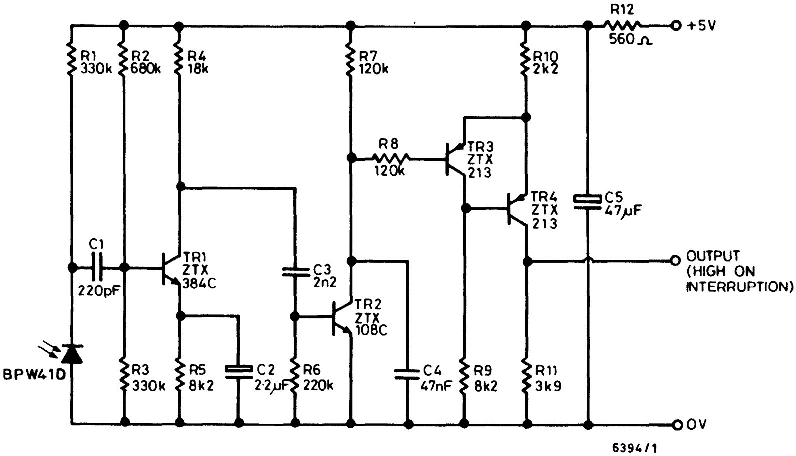


Fig. 19. Short Range Detector Circuit

Beam Interruption Long Range Detector

This longer range detector can be used in applications such as burglar alarms, automatic door or gate openers etc. In this circuit (shown in Fig. 20) the BPW41D photodiode is used with an acitve load because ambient lighting conditions are much less controllable in long range systems, and this load will be unaffected by high background light levels.

The improvement in range over the simple detector circuit is achieved by using a higher gain amplifier to boost the output of the BPW41D photodiode before feeding it to a pulse detector. The pulse detector drives a level sensor which produces a low output when the transmitter beam is broken. A small percentage of the output is fed back to the input of the level sensor to give the hysteresis necessary for noise free output switching. The level sensor output is capable of driving a normal TTL logic gate if required.

The maximum range of operation with this detector is approximately 6m. Using a lens with the transmitter as described with the short range detector, a range of over 40m has been achieved.

During construction the active load and amplifier should be carefully laid out to avoid unwanted feedback. The unit should be mounted in a screened box to minimise interference.

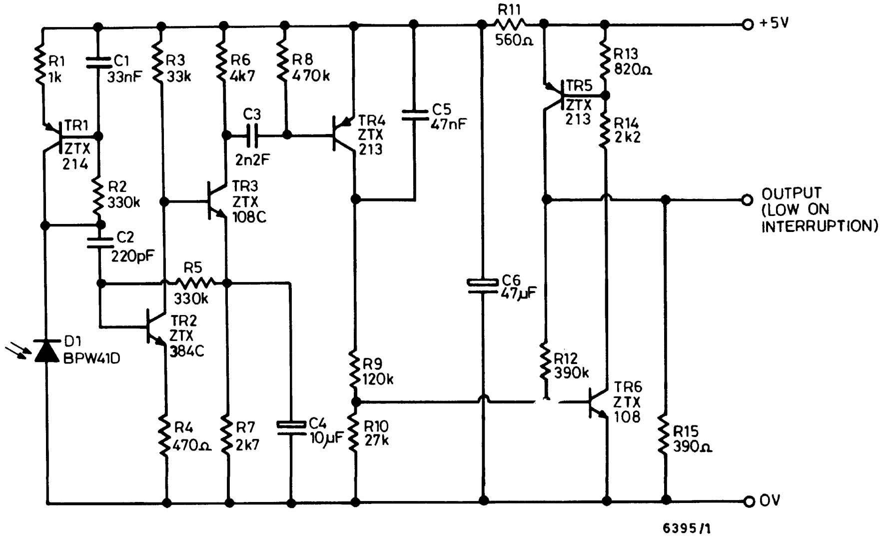


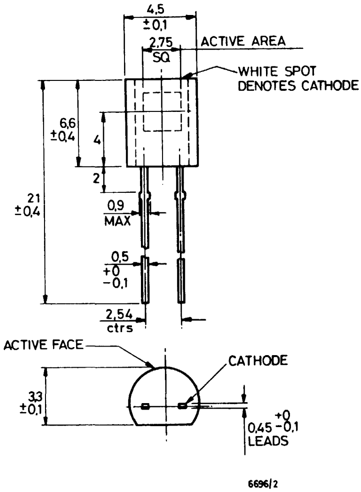
Fig. 20. Long Range Detector Circuit

OPTO-ELECTRONIC SEMICONDUCTOR DICE

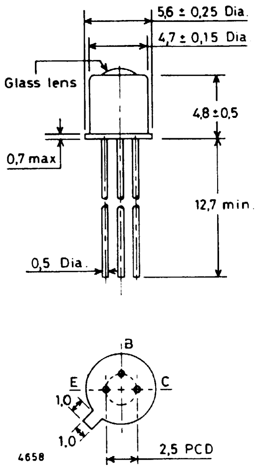
The majority of Ferranti Opto-electronic semiconductors are available as unencapsulated dice or in wafer form, details of which can be obtained on request from Discrete Component Marketing.

Information concerning phototransistor dice, their specifications and inspection routes together with various testing and shipping options is contained within the hand-book FSD1001 Issue 4, also available on request.

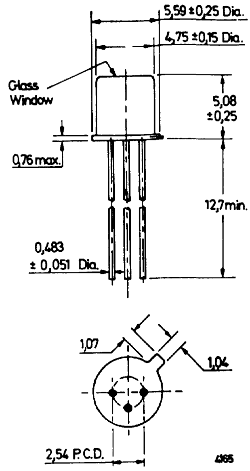
PACKAGE OUTLINES



BPW41D

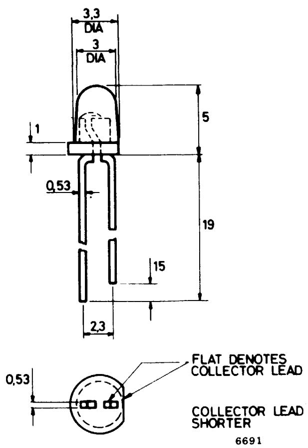


BPX25
ZM100
ZM110

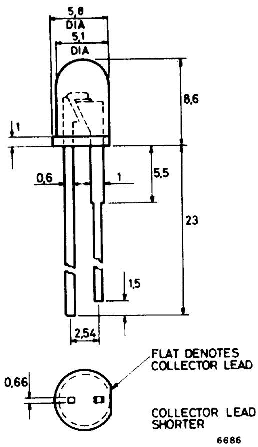


BPX29

PACKAGE OUTLINES

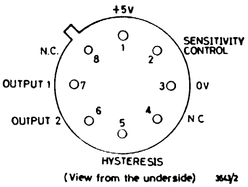


ZMP31

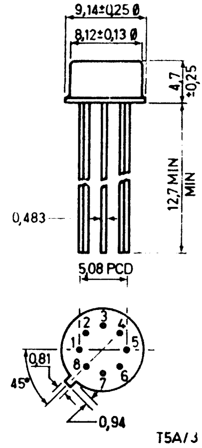


ZMP51

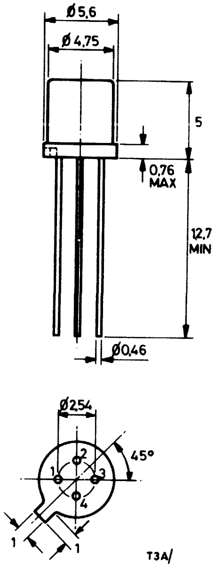
Dimensions in millimetres

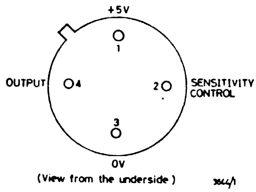


External Hysteresis Resistor
connected between pins 5 and 7



ZNP100 8-lead TO-5 with glass window





ZNP102, ZNP103
4-lead TO-72 with glass window

All dimensions in millimetres

COMPETITOR CROSS REFERENCE LIST

The following cross-reference list has been compiled as a guide for design engineers and purchasing agents and indicates the nearest Ferranti equivalent to a variety of competitive manufacturer's devices. In some cases there will be minor differences in electrical characteristics and/or package details and acceptability may be first determined by reviewing the data presented in this catalogue.

Additional informtion, if requested, may be obtained by contacting Ferranti Electronics Limited, Discrete Component Marketing.

The data contained in this guide is believed to be accurate. However, no responsibility is assumed by Ferranti Electronics Limited for the use of this data in actual circuit design.

Competitive Part Number	Device Type	Ferranti Equivalent
BPW30	Photodarlington	ZM100
BPW41	Infra-Red Response Photodiode	BPW41D
BPX25	Phototransistor	BPX25
BPX29	Phototransistor	BPX29
BPX31	Phototransistor	ZM110
BPX43	Phototransistor	ZM110
BPX99	Phototransistor	ZM110
BPY62	Phototransistor	ZM110
FPT120A	Phototransistor	ZM110
FPT120B	Phototransistor	ZM110
FPT120C	Phototransistor	ZM110
FPT130A	Phototransistor	ZM110
FPT130B	Phototransistor	ZM110
FPT220	Phototransistor	ZM110
FPT230	Phototransistor	ZM110
FPT320	Phototransistor	ZM110
FPT330	Phototransistor	ZM110
FPT400	Phototransistor	ZM110
FPT410	Phototransistor	ZM110
FPT500	Phototransistor	ZM110
FPT530	Phototransistor	ZM110
FPT560	Photodarlington	ZM100
MRD300	Phototransistor	ZM110
MRD310	Phototransistor	ZM110
MRD370	Photodarlington	ZM100
MRD810	Phototransistor	ZM110
MRD3050	Phototransistor	BPX29
MRD3051	Phototransistor	BPX29
MRD3052	Phototransistor	BPX29
MRD3053	Phototransistor	BPX29
MRD3054	Phototransistor	ZM110
MRD3055	Phototransistor	ZM110
MRD3056	Phototransistor	ZM110
MT1	Phototransistor	ZM110
MT2	Phototransistor	ZM110
SFH205	Infra-red Response Photodiode	BPW41D
TIL81	Phototransistor	ZM110
TIL100	Infra-red Response Photodiode	BPW41D

CONVERSION OF PHOTOMETRIC ILLUMINANCE UNITS

Unit Required	Unit Given		
	Phot (lm/cm^2)	Lux (lm/m^2)	Foot-candle (lm/ft^2)
Phot (lm/cm^2)	1	10^{-4}	1.076×10^{-3}
Lux (lm/m^2)	10^4	1	10.76
Foot-candle (lm/ft^2)	929.4	0.0929	1