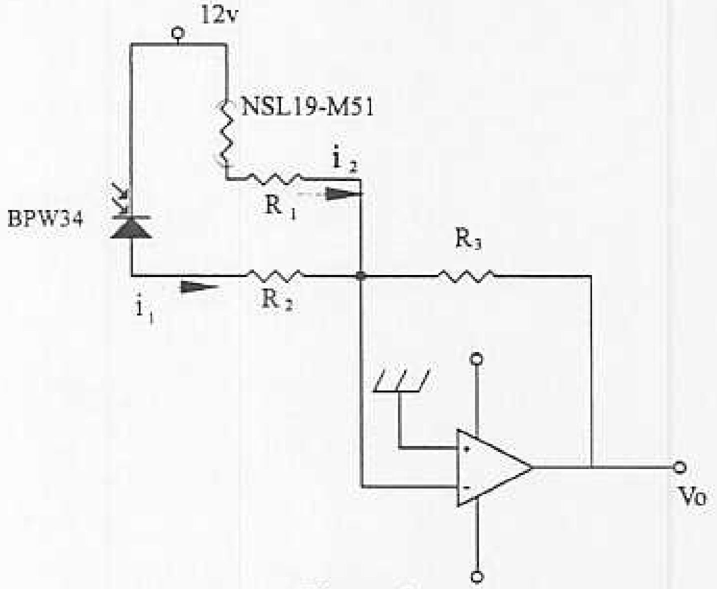
UNIVERSIDAD CARLOS III DE MADRID
ESCUELA POLITÉCNICA SUPERIOR

EXAMEN DE INSTRUMENTACION ELECTRONICA I
2° CURSO INGENIERÍA TÉCNICA EN ELECTRÓNICA INDUSTRIAL

6 de Febrero de 1996

DURACIÓN: 3 H 30 M

1. Se desea comparar las características de dos sensores de iluminancia: una LDR y un fotodiodo cuyas hojas de características se adjuntan. Para ello se propone el circuito sumador de la Figura 1 que permite obtener una salida proporcional a la suma de las señales de entrada.



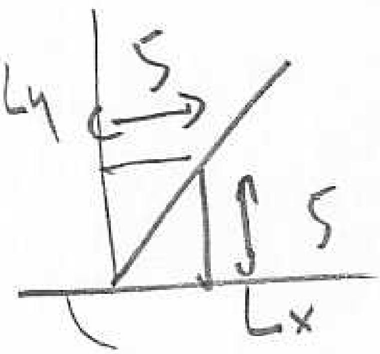


Figura 1

1h.

(2 puntos)

(a) Calcular v_o en función de las corrientes i_1 e i_2. ¿Qué parámetros fijan los valores de dichas corrientes en la expresión de v_o? ¿Tiene v_o un comportamiento lineal con la iluminancia (lux) de la radiación incidente? ¿Por qué? 1.

(b) ¿Qué sensor tiene una mayor respuesta espectral? 0.5

(c)Ajuste los valores de las resistencias que sean necesarios para que v_o tenga la misma contribución de ambos sensores para una iluminancia de ~~500~~ 10^4 lux . 0.5

2. Se diseña un acelerómetro para la medida de aceleraciones según el esquema de la Figura2. Los datos de la galga se encuentran en la hoja de características que se adjunta,

$L_y = L_x$ $L_y = L x^a$ → $y = x^a$

$y = x$ $L_y = a L_x$

mientras que los de la ménsula (probeta) son: módulo de elasticidad $E=10^8$ N/m^2, módulo de Poisson $\upsilon=0.3$, sección transversal $s=2\ 10^{-4}$ m^2.

1h.

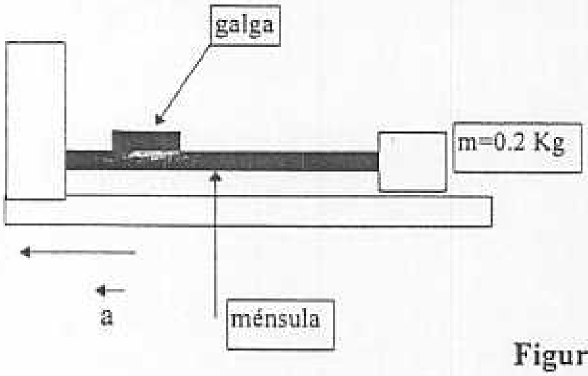


Figura 2

(3 puntos)

(a) Explique su principio de funcionamiento de forma breve y concisa.

(b) Calcule la sensibilidad del acelerómetro en Ω/g.

(c) Diseñe un circuito acondicionador de la señal para el acelerómetro de la Figura 2 utilizando un puente de Wheatstone y el amplificador de instrumentación AD620 cuyas hojas de características se adjuntan:

c.1 Especifique la orientación de las galgas extensométricas en la ménsula y su colocación en el puente. El montaje en el puente ha de ser tal que permita **máxima sensibilidad y compensación de la temperatura.** Explique razonadamente su diseño.

c.2. Calcule la sensibilidad del puente en mv/g. Si no se calculó la sensibilidad del acelerómetro en el apartado (b), suponga $S_a=2\ 10^{-2}$ Ω/g. La alimentación del puente es de 12 v. ¿Cómo afecta dicho valor de la tensión de alimentación a la sensibilidad del puente?. ¿Cómo influye en el funcionamiento de la galga?

c.3 Determine los valores exactos que deben tener las resistencias del puente para que se anule la tensión de desequilibrio del puente cuando no se aplica aceleración.

c.4 Calcule el valor de la resistencia que fija la ganancia del amplificador de instrumentación para obtener un rango de señal de salida de 0 a 10v en la medida de aceleraciones de 0 a 200 g. Si no calculó antes la sensibilidad del puente suponga $S_p=0{,}65$mv/g.

c.5 ¿Qué ventajas presenta el utilizar el puente de Wheatstone frente a un circuito potenciométrico?. Mencione 3 razones que exijan el uso de un amplificador de instrumentación a la salida del puente de Wheatstone.

3. Se desea medir la temperatura dentro de una cubeta en un rango de 20 a 80°C, de forma que la tensión de salida varíe de 0 a -10v. Para ello se propone el circuito de la Figura 3.

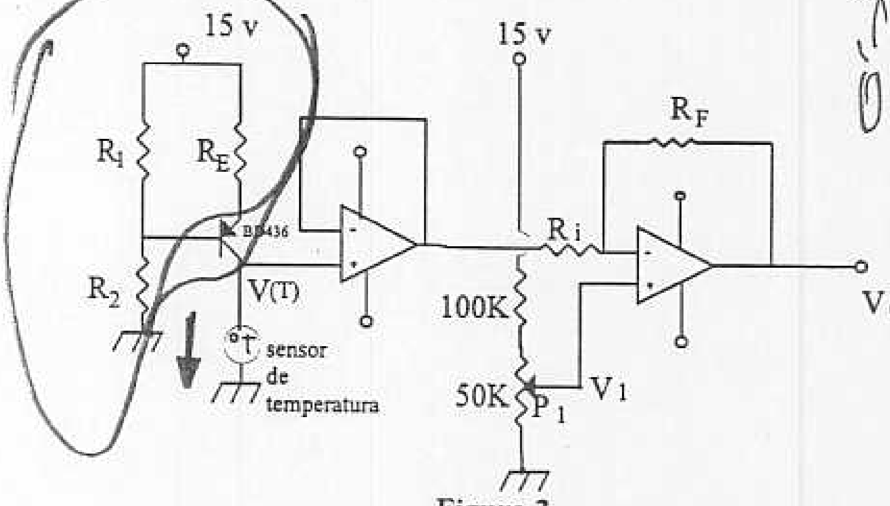


Figura 3

(2 puntos)

(a) Calcule la tensión de salida v_o, en función de v_1 y de la tensión v(T) a la salida del sensor de temperatura. ¿Se obtiene una función lineal si se supone que v(T) varía linealmente con la temperatura? ¿Qué fija la posición del potenciómetro P_1? ¿Cómo se consiguen los -10v de fondo de escala para la temperatura de 80°C? ¿Qué función tiene cada etapa con amplificador operacional?

(b) Si se utiliza como sensor de temperatura una RTD lineal que tiene una resistencia de 141 Ω a 50 °C, un coeficiente de variación con la temperatura de 0.004/°C y que disipa una potencia de 30mw/°C:

b.1 ¿Cuál es la corriente máxima que puede circular por la RTD para poder medir con un error inferior a 0.1°C?

b.2 ¿Cuáles deben ser los valores de R_1, R_2, R_E para que la fuente de corriente suministre un 50% de dicha corriente máxima? (Suponga i_{MAX}=1,5mA si no fue calculada en el apartado anterior).

b.3 Supuesta la red de polarización diseñada en la etapa anterior, ¿qué ganancia debe suministrar la etapa inversora para conseguir el rango de señal de salida deseado? ¿Cuáles han de ser los valores de R_i y R_F? ¿Cuál ha de ser la posición del cursor P_1?

(c)Sea un termistor NTC con una variación de -10%/°C, una resistencia de 3.5KΩ a 20 °C y una potencia disipada de P_D=5mw/°C. Si se coloca esta NTC en lugar de la RTD en el montaje diseñado en el apartado anterior (con los mismos valores para todos los componentes), ¿qué error mínimo se cometería en la medida de temperatura?

(d) ¿Qué otros sensores de temperatura eléctricos conoce?. Enumérelos y especifique una de sus características más sobresaliente frente a los otros.

4. Se utiliza un sensor de posición potenciométrico para medir desplazamientos de 0 a 10cm de una pieza móvil, como se muestra en la Figura 4, la resistencia varía linealmente en este rango de 0 a 2KΩ.

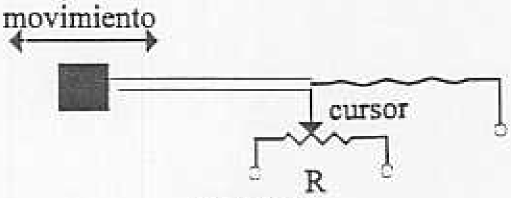


Figura 4

20

(1 punto)

(a) Diseñe un circuito acondicionador que proporcione una salida lineal de 0 a 5v.

(b) ¿Qué otro tipo de transductores pasivos basados en la variación de impedancia se pueden utilizar en la medida de desplazamientos? Enumérelos y descríbalos brevemente.

5. Explique cualitativamente las variaciones de las tensiones y corrientes indicadas en la Figura 5, ante un aumento de la tensión E.

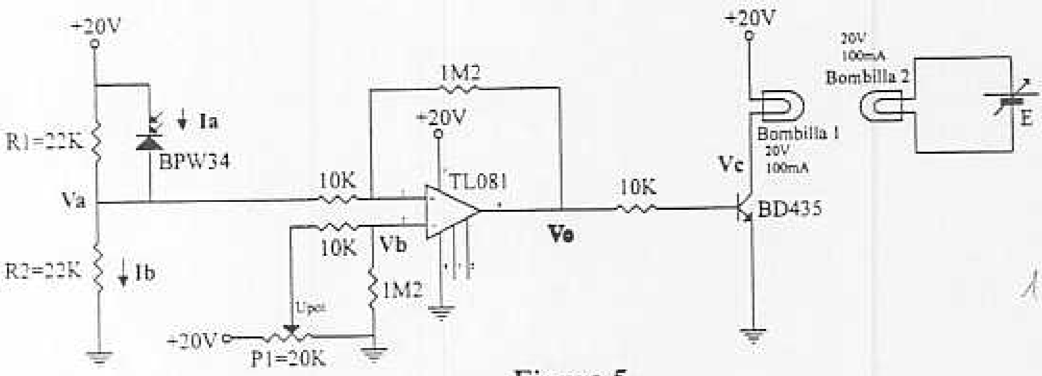


Figura 5

15

(1 punto)

6. -Explicar brevemente el funcionamiento del circuito mostrado en la Figura 6, indicando de qué etapas está compuesto.

-Sabiendo que la resistencia de salida del sensor de Efecto Hall es 50Ω, ¿qué constante de tiempo rige la carga del condensador C1?, ¿Qué tipo de filtro es?, ¿Cúal es su frecuencia de corte?.

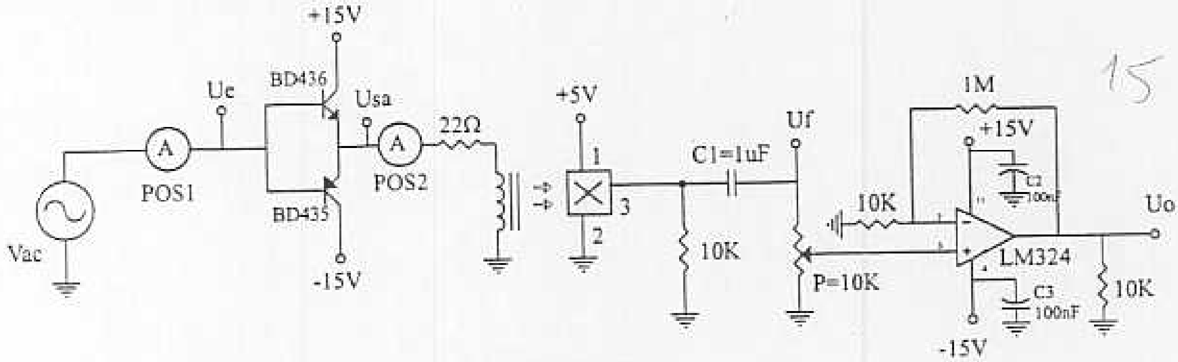


Figura 6

15

(1 punto)

RS Data Library

Light dependent resistors

NORP12 RS stock numbers 651-507
NSL19-M51 RS stock number 596-141

Two cadmium sulphide (cdS) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Guide to source illuminations

Light source	Illumination (Lux)
Moonlight	0.1
60W bulb at 1m	50
1W MES bulb at 0.1m	100
Fluorescent lighting	500
Bright sunlight	30,000

Circuit symbol

Light memory characteristics

Light dependent resistors have a particular property in that they remember the lighting conditions in which they have been stored. This memory effect can be minimised by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values.

NORP12 (RS stock no. 651-507)

Absolute maximum ratings

Voltage, ac or dc peak	320V
Current	75mA
Power dissipation at 30°C	250mW
Operating temperature range	-60°C to +75°C

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux	-	400	-	Ω
	10 lux	-	9		kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5		pF
Rise time 1	1000 lux	-	2.8		ms
	10 lux	-	18		ms
Fall time 2	1000 lux	-	48	-	ms
	10 lux	-	120		ms

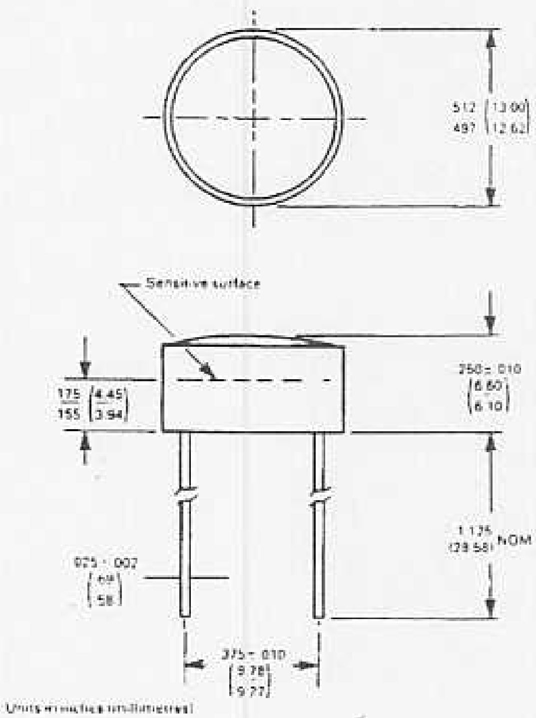
1. Dark to 110% R_L
2. To 10 × R_L

R_L = photocell resistance under given illumination.

Features

- Wide spectral response
- Low cost
- Wide ambient temperature range

Dimensions



NSL19-M51

Absolute maximum ratings

Voltage ac or dc peak ______ 100V
Current ______ 5mA
Power dissipation at 25°C ______ 50mW*
Operating temperature range ______ -25°C +75°C

Electrical characteristics

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	10 lux 100 lux	20	[illegible] 5	100	kΩ kΩ
Dark resistance	10 lux after 10 sec	20		-	MΩ
Spectral response	-		550		nm
Rise time	10ftc		45	-	ms
Fall time	10ftc		55	-	ms

Dimensions

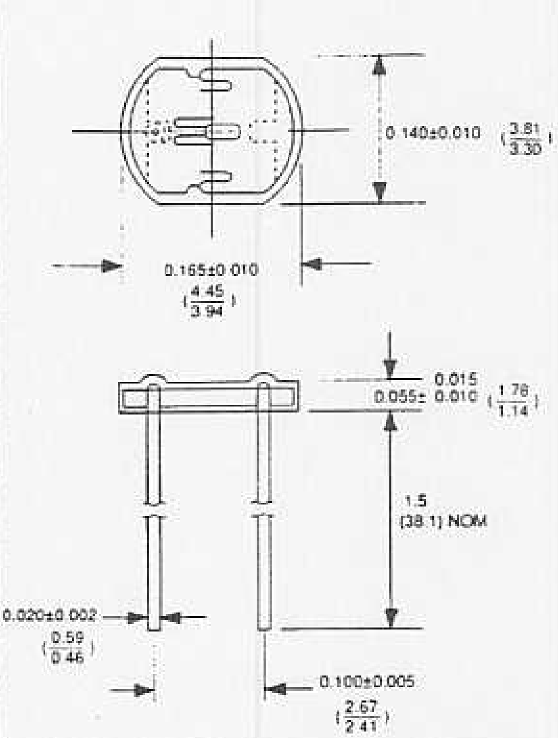


Figure 4 Resistance as a function illumination

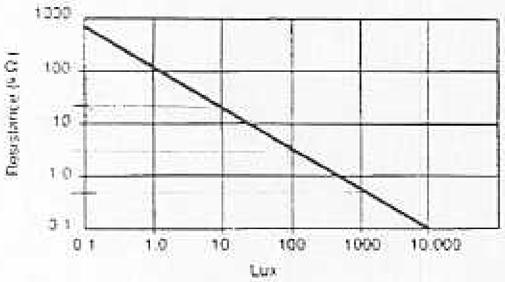
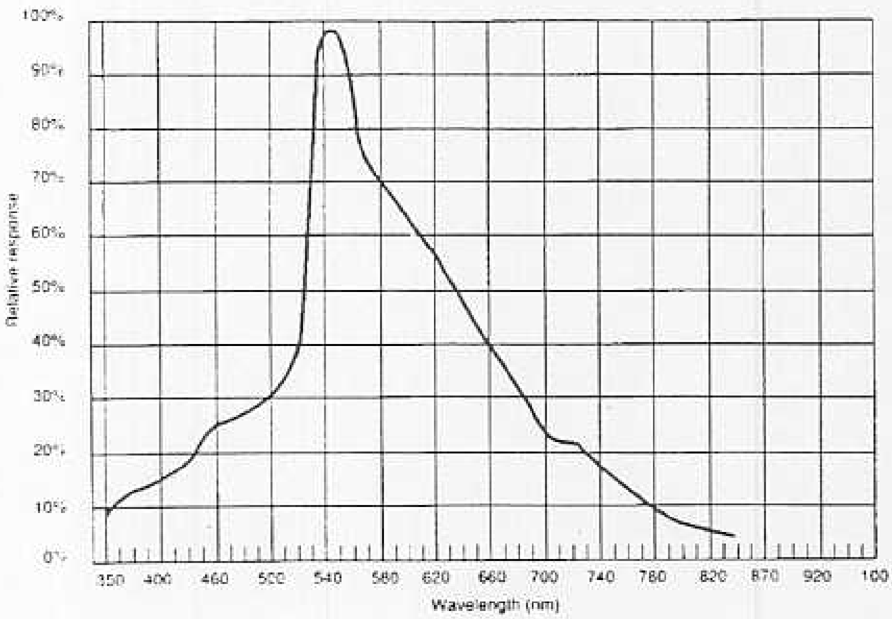


Figure 5 Spectral response



$R_0 = 100k\Omega \quad \Phi_0 = 1\,lux$

$\Phi_1 = 100\,lux \Rightarrow R = 100k\,e$

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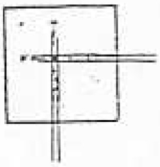
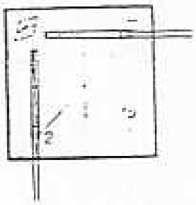
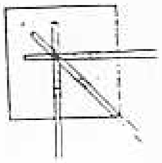
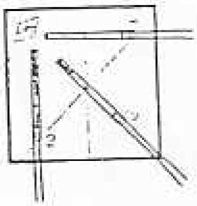
COMPATIBLE ADHESIVES & OPERATIONAL TEMPERATURE RANGE

- ● P-2 ·············· −30 ~ +80°C
- ● CN ·············· −30 ~ +80°C
- ● NP-50 ·········· −30 ~ +80°C
- ● PS ·············· −30 ~ +80°C
- ● EA-2 ········· −196 ~ +80°C
- ● RP-2 ··········· −30 ~ +80°C

* FOIL GAUGE-SERIES "PF"

Gauge Pattern Leads attached	Type	Dimensions (mm)			Nominal Resistance (Ω)	Gauge Factor (approx.)	Gauges per Package
		Gauge Length	Gauge Width	Backing			
	PFL-10-11	10	0.9	18×6	120±0.3	2.1	10
	PFL-20-11	20	1.4	28×6	120±0.3	2.1	10
	PFC-10-11	10	0.9	18×18	120±0.5	2.1	6
	PFC-20-11	20	1.4	28×28	120±0.5	2.1	6
	PFCS-10-11	10	0.9	21×21	120±0.5	2.1	6
	PFR-10-11	10	0.9	18×18	120±0.5	2.1	6
	PFR-20-11	20	1.4	28×28	120±0.5	2.1	6
	PFRS-10-11	10	0.9	21×21	120±0.5	2.1	6

* "PF" series gauges are temperature compensated for mild steel only.

HIGH ACCURACY A/D CONVERTERS

Very high accuracy and high resolution floating-point A/D con-verters can be achieved by the incorporation of offset and gain calibration routines. There are two techniques commonly used for calibration, a hardware circuit as shown in Figure 43 and/or a software routine. In this application the microprocessor is functioning as the autoranging circuit, requiring software over-head; therefore, a hardware calibration technique was applied which reduces the software burden. The software is used to set the gain of the AD526. In operation the signal is converted, and if the MSB of the AD574 is not equal to a logical 1, the gain is increased by binary steps, up to the maximum gain. This maximizes the full-scale range of the conversion process and insures a wide dynamic range.

The calibration technique uses two point correction, offset and gain. The hardware is simplified by the use of programmable magnitude comparators, the 74ALS528s, which can be "burned" for a particular code. In order to prevent under or over range hunting during the calibration process, the reference offset and gain codes should be different from the endpoint codes. A calibration cycle consists of selecting whether gain or offset is to be calibrated then selecting the appropriate multiplexer channel to apply the reference voltage to the signal channel. Once the operation has been initiated, the counter, a 74ALS869, drives the D/A converter in a linear fashion providing a small correction voltage to either the gain or offset trim point of the AD574. The output of the A/D converter is then compared to the value preset in the 74ALS528 to determine a match. Once a match is detected, the 74ALS528 produces a low going pulse which stops the counter. The code at the D/A converter is latched until the next calibration cycle. Calibration cycles are under the control of the microprocessor in this application and should be implemented only during periods of converter inactivity.

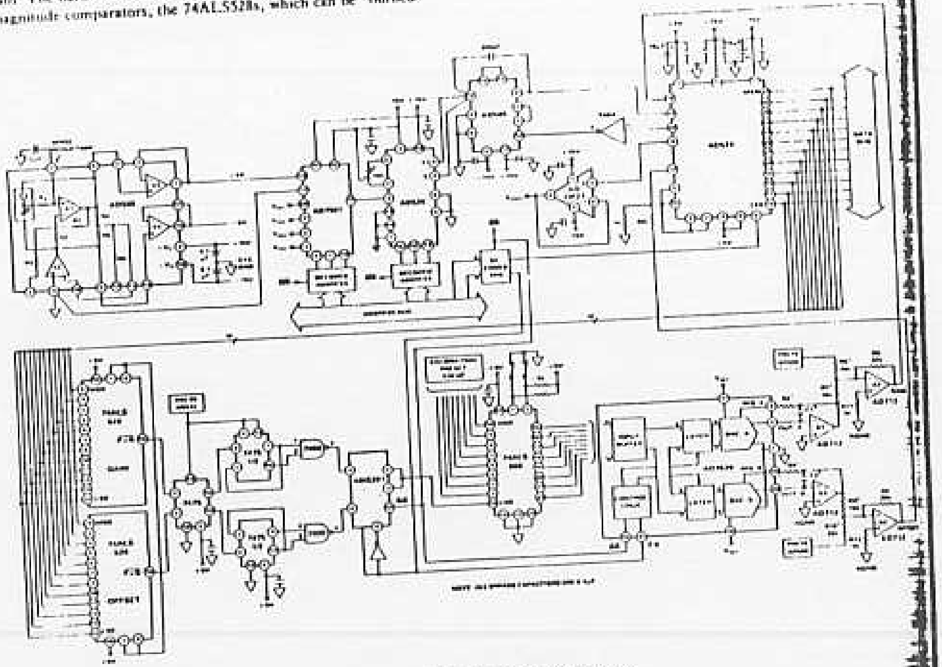


Figure 43. High Accuracy A/D Converter

ANALOG DEVICES

Low Cost, Low Power Instrumentation Amplifier

AD620

FEATURES

EASY TO USE
Gain Set with One External Resistor
(Gain Range 1 to 1000)
Wide Power Supply Range (±2.3 V to ±18 V)
Higher Performance than Three Op Amp IA Designs
Available in 8 Pin DIP and SOIC Packaging
Low Power, 1.3 mA max Supply Current

EXCELLENT DC PERFORMANCE ("A GRADE")
125 μV max, Input Offset Voltage (50 μV max "B" Grade)
1 μV/°C max, Input Offset Drift
2.0 nA max, Input Bias Current
93 dB min Common-Mode Rejection Ratio (G = 10)

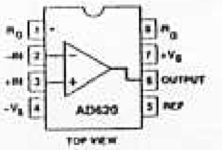
LOW NOISE
9 nV/√Hz, @ 1 kHz, Input Voltage Noise
0.28 μV p-p Noise (0.1 Hz to 10 Hz)

EXCELLENT AC SPECIFICATIONS
120 kHz Bandwidth (G = 100)
15 μs Settling Time to 0.01%

APPLICATIONS
Weigh Scales
ECG and Medical Instrumentation
Transducer Interface
Data Acquisition Systems
Industrial Process Controls
Battery Powered and Portable Equipment

CONNECTION DIAGRAM

8-Pin Plastic Mini-DIP (N), Cerdip (Q) and SOIC (R) Packages

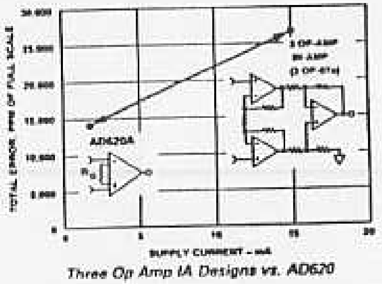


PRODUCT DESCRIPTION

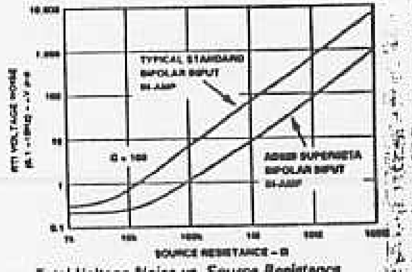
The AD620 is a low cost, high accuracy instrumentation amplifier which requires only one external resistor to set gains of 1 to 1000. Furthermore, the AD620 features 8-pin SOIC and DIP packaging that is smaller than discrete designs, and offers lower power (only 1.3 mA max supply current), making it a good fit for battery powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum non-linearity, low offset voltage of 50 μV max and offset drift of 0.6 μV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Further-more, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with the use of Superβeta processing in the input stage. The AD620 works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 μV p-p in the 0.1 Hz to 10 Hz band, 0.1 pA/√Hz input current noise. Also, the AD620 is well suited for multiplexed applications with its settling time of 15 μs to 0.01% and its cost is low enough to enable designs with one in-amp per channel.



Three Op Amp IA Designs vs. AD620



Total Voltage Noise vs. Source Resistance

4

Model	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Units
GAIN	$G = 1 + (49.4\,k/R_G)$										
Gain Range		1		10,000	1		10,000	1		10,000	
Gain Error[2]	$V_{OUT} = \pm 10$ V										
G = 1			0.01	0.10		0.01	0.02		0.03	0.10	%
G = 10			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 100			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 1000			0.40	0.70		0.35	0.50		0.40	0.70	%
Nonlinearity,	$V_{OUT} = -10$ V to $+10$ V,										
G = 1–1000	$R_L = 10$ kΩ		10	40		10	40		10	40	ppm
G = 1–100	$R_L = 2$ kΩ		10	95		10	95		10	95	ppm
Gain vs. Temperature	Gain > 1[2]			50			50			50	ppm/°C
VOLTAGE OFFSET	(Total RTI Error = $V_{OSI} + V_{OSO}/G$)										
Input Offset, V_{OSI}	$V_S = \pm 5$ V to ± 15 V		30	125		15	50		30	125	μV
over Temperature	$V_S = \pm 5$ V to ± 15 V			185			85			225	μV
Average TC	$V_S = \pm 5$ V to ± 15 V		0.3	1.0		0.1	0.6		0.3	1.0	μV/°C
Output Offset, V_{OSO}	$V_S = \pm 15$ V		400	1000		200	500		400	1000	μV
	$V_S = \pm 5$ V			1500			750			1500	μV
over Temperature	$V_S = \pm 5$ V to ± 15 V			2000			1000			2000	μV
Average TC	$V_S = \pm 5$ V to ± 15 V		5.0	15		2.5	7.0		5.0	15	μV/°C
Offset Referred to the Input vs. Supply (PSR)	$V_S = \pm 2.3$ V to ± 18 V										
G = 1		80	100		80	100		80	100		dB
G = 10		95	120		100	120		95	120		dB
G = 100		110	140		120	140		110	140		dB
G = 1000		110	140		120	140		110	140		dB
INPUT CURRENT											
Input Bias Current			0.5	2.0		0.5	1.0		0.5	2	nA
over Temperature				2.5			1.5			4	nA
Average TC			3.0			3.0			8.0		pA/°C
Input Offset Current			0.3	1.0		0.3	0.5		0.3	1.0	nA
over Temperature				1.5			0.75			2.0	nA
Average TC			1.5			1.5			8.0		pA/°C
INPUT											
Input Impedance											
Differential			10‖2			10‖2			10‖2		GΩ‖pF
Common Mode			10‖2			10‖2			10‖2		GΩ‖pF
Input Voltage Range[3]	$V_S = \pm 2.3$ V to ± 5 V	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	V
over Temperature		$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	V
	$V_S = \pm 5$ V to ± 18 V	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	V
over Temperature		$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.1$		$+V_S - 1.4$	V
Common-Mode Rejection Ratio DC to 60 Hz with 1 kΩ Source Imbalance	$V_{CM} = 0$ V to ± 10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	$R_L = 10$ kΩ, $V_S = \pm 2.3$ V to ± 5 V	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	V
over Temperature		$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.6$		$+V_S - 1.3$	V
	$V_S = \pm 5$ V to ± 18 V	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$+V_S - 1.4$	V
over Temperature		$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 2.3$		$+V_S - 1.5$	V
Short Current Circuit			±18			±18			±18		mA

Model	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[4] Min	AD620S[4] Typ	AD620S[4] Max	Units
DYNAMIC RESPONSE											
Small Signal –3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
Slew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/μs
Settling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		μs
G = 1000			150			150			150		μs
NOISE											
Voltage Noise, 1 kHz	Total RTI Noise = $\sqrt{(e_{ni})^2 + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	μV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	μV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	μV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p
REFERENCE INPUT											
R_{IN}			20			20			20		kΩ
I_{IN}	$V_{IN+}, V_{REF} = 0$		+50	+60		+50	+60		+50	+60	μA
Voltage Range		$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	V
Gain to Output			1 ± 0.0001			1 ± 0.0001			1 ± 0.0001		
POWER SUPPLY											
Operating Range[3]		±2.3		±18	±2.3		±18	±2.3		±18	V
Quiescent Current	$V_S = \pm 2.3$ V to ± 18 V		0.9	1.3		0.9	1.3		0.9	1.3	mA
over Temperature			1.1	1.6		1.1	1.6		1.1	1.6	mA
TEMPERATURE RANGE											
For Specified Performance			−40 to +85			−40 to +85			−55 to +125		°C

NOTES

[1]Does not include effects of external resistor R_G.

[2]One input grounded. G = 1.

[3]This is defined as the same supply range which is used to specify PSR.

[4]See Analog Devices military data sheet for 883B tested specifications.

Specifications subject to change without notice.

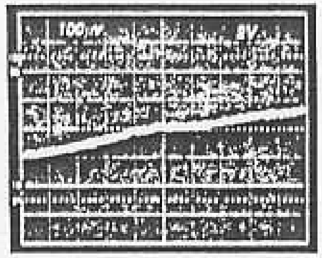


Figure 29b. Gain Nonlinearity, $G = 100$, $R_L = 10\ k\Omega$ (100 µV = 10 ppm)

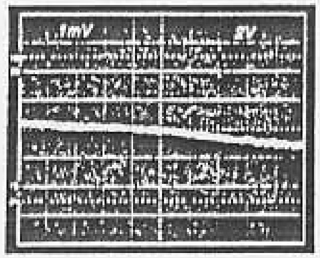


Figure 29c. Gain Nonlinearity, $G = 1000$, $R_L = 10\ k\Omega$ (1 mV = 100 ppm)

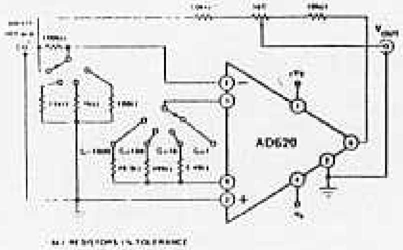


Figure 30. Settling Time Test Circuit

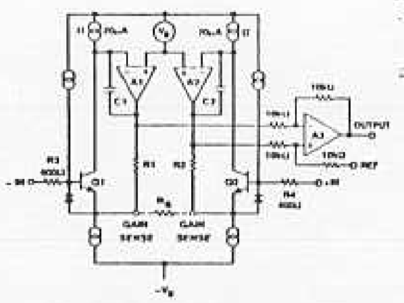


Figure 31. Simplified Schematic of AD620

THEORY OF OPERATION

The AD620 is a monolithic instrumentation amplifier based on a modification of the classic three op amp approach. Absolute value trimming allows the user to program gain *accurately* (to 0.15% at G = 100) with only one resistor. Monolithic construction and laser wafer trimming allow the tight matching and tracking of circuit components, thus insuring the high level of performance inherent in this circuit.

The input transistors Q1 and Q2 provide a single differential-pair bipolar input for high precision (Figure 31), yet offer 10× lower Input Bias Current thanks to Superβeta processing. Feedback through the Q1-A1-R1 loop and the Q2-A2-R2 loop maintains constant collector current of the input devices Q1, Q2 thereby impressing the input voltage across the external gain-setting resistor R_G. This creates a differential gain from the inputs to the A1/A2 outputs given by $G = (R1 + R2)/R_G + 1$. The unity-gain subtractor A3 removes any common-mode signal, yielding a single-ended output referred to the REF pin potential.

The value of R_G also determines the transconductance of the preamp stage. As R_G is reduced for larger gains, the transconductance increases asymptotically to that of the input transistors. This has three important advantages: (a) Open-loop gain is boosted for increasing programmed gain, thus reducing gain-related errors. (b) The gain-bandwidth product (determined by C1, C2 and the preamp transconductance) increases with programmed gain, thus optimizing frequency response. (c) The input voltage noise is reduced to a value of 9 nV/$\sqrt{Hz}$, determined mainly by the collector current and base resistance of the input devices.

The internal gain resistors, R1 and R2, are trimmed to an absolute value of 24.7 kΩ, allowing the gain to be programmed accurately with a single external resistor.

The gain equation is then

$$G = \frac{49.4\ k\Omega}{R_G} + 1$$

so that

$$R_G = \frac{49.4\ k\Omega}{G - 1}$$

Make vs. Buy: A Typical Bridge Application Error Budget

The AD620 offers improved performance over "homebrew" three op amp IA designs, along with smaller size, less components and 10× lower supply current. In the typical application, shown in Figure 32, a gain of 100 is required to amplify a bridge output of 20 mV full scale over the industrial temperature range of −40°C to +85°C. The error budget table below shows how to calculate the effect various error sources have on circuit accuracy.

Regardless of the system it is being used in, the AD620 provides greater accuracy, and at low power and price. In simple systems, absolute accuracy and drift errors are by far the most significant contributors to error. In more complex systems with an intelligent processor, an auto-gain/auto-zero cycle will remove all absolute accuracy and drift errors leaving only the resolution errors of gain nonlinearity and noise, thus allowing full 14-bit accuracy.

Note that for the homebrew circuit, the OP-07 specifications for input voltage offset and noise have been multiplied by $\sqrt{2}$. This is because a three op amp type in amp has two op amps at its inputs, both contributing to the overall input error.

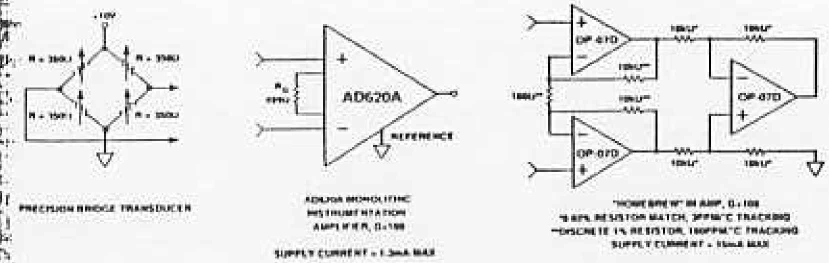


Figure 32. Make vs. Buy

Table I. Make vs. Buy Error Budget

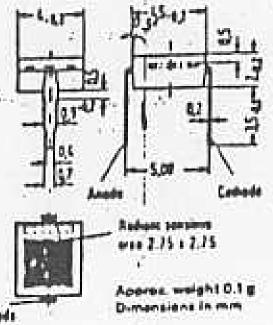
Error Source	AD620 Circuit Calculation	"Homebrew" Circuit Calculation	Error, ppm of Full Scale AD620	Error, ppm of Full Scale Homebrew
ABSOLUTE ACCURACY at T_A = +25°C				
Input Offset Voltage, µV	125 µV/20 mV	(150 µV × $\sqrt{2}$)/20 mV	6,250	10,607
Output Offset Voltage, µV	1000 µV/100/20 mV	((150 µV × 2)/100)/20 mV	500	150
Input Offset Current, nA	2 nA × 350 Ω/20 mV	(6 nA × 350 Ω)/20 mV	18	53
CMR, dB	110 dB→3.16 ppm, × 5 V/20 mV	(0.02% Match × 5 V)/20 mV	791	4,988
		Total Absolute Error	7,558	15,797
DRIFT TO +85°C				
Gain Drift, ppm/°C	(50 ppm + 10 ppm) × 60°C	10 ppm/°C Track × 60°C	3,600	600
Input Offset Voltage Drift, µV/°C	1 µV/°C × 60°C/20 mV	(2.5 µV/°C × $\sqrt{2}$ × 60°C)/20 mV	3,000	10,607
Output Offset Voltage Drift, µV/°C	15 µV/°C × 60°C/100/20 mV	(2.5 µV/°C × 2 × 60°C)/100/20 mV	450	150
		Total Drift Error	7,050	11,357
RESOLUTION				
Gain Nonlinearity, ppm of Full Scale	40 ppm	40 ppm	40	40
Typ 0.1 Hz–10 Hz Voltage Noise, µV p-p	0.28 µV p-p/20 mV	(0.38 µV p-p × $\sqrt{2}$)/20 mV	14	27
		Total Resolution Error	54	67
		Grand Total Error	14,662	27,221

(G = 100, V_S = ±15 V.
All errors are min/max and referred to input.)

Plastic-Encapsulated Silicon PIN Photodiode

BPW 34

The PBW 34 is a silicon planar PIN photodiode incorporated in a transparent plastic package. Its terminals are soldering tabs arranged in 5.08 mm (2/10") spacing. Due to its design the diode can also very easily be assembled on PC boards. The planar reverse side of the plastic package provides for stable fixing. Arrays can be implemented by multiple arrangements. This versatile photodetector can be used as a diode as well as a voltaic cell. The signal/noise ratio is particularly favorable, even at low illuminance. The open-circuit voltage at low illuminance is higher than with comparable mesa photovoltaic cells. The PIN photodiode is outstanding for low junction capacitance, high cut-off frequency and fast switching times. The photodiode is particularly suitable for IR sound transmission. The cathode is marked by a projection at the soldering tab.



Maximum ratings

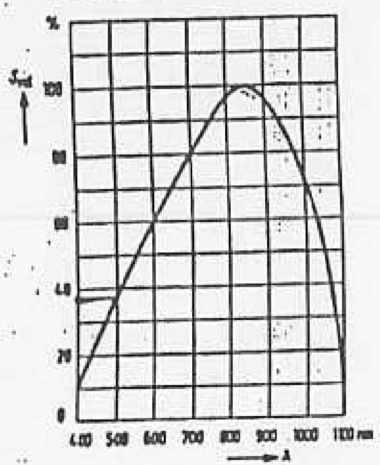
Reverse voltage	V_R	32	V
Operating and storage temperature range	T_{stg}	−40 to +80	°C
Soldering temperature at 2 mm distance to the case bottom ($t \leq 3$)	T_{sold}	230	°C
Total power dissipation (T_A = 25 °C)	P_{tot}	150	mW

Characteristics (T_A = 25 °C)

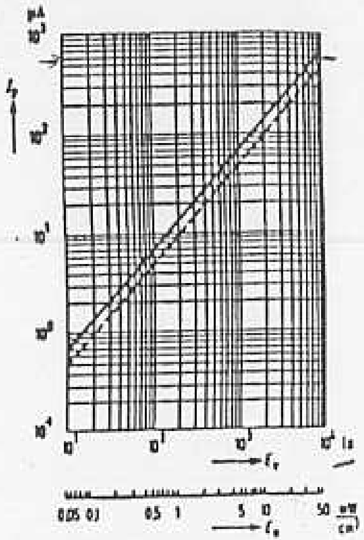
Spectral sensitivity[1] (V_R = 5 V)	S	70 (≥ 50)	nA/lx
Wavelength of the max. sensitivity	$\lambda_{S\,max}$	850	nm
Quantum yield (electrons per photon) (λ = 850 nm)	η	0.88	Electrons/Photon
Spectral sensitivity (λ = 850 nm)	S_λ	0.60	A/W
Open-circuit voltage (E_v = 100 lx)[1]	V_L	285	mV
Open-circuit voltage (E_v = 1000 lx)[1]	V_L	365	mV
Short-circuit current (E_v = 100 lx)[1]	I_s	6.5	µA
Rise and fall time of the photocurrent from 10% to 90% and from 90% to 10% of the final value			
(R_L = 1 kΩ; V_R = 0 V; λ = 850 nm)	t_r; t_f	125	ns
(R_L = 1 kΩ; V_R = 10 V; λ = 850 nm)	t_r; t_f	50	ns
Temperature coefficient of V_0	TC	−2.6	mV/K
Temperature coefficient of I_s or I_p resp.	TC	0.18	%/K
Capacitance			
(V_R = 0 V; f = 1 MHz; E = 0)	C_0	72	pF
(V_R = 3 V; f = 1 MHz; E = 0)	C_3	25 (≤ 40)	pF
Radiant sensitive area	A	7.6	mm²
Dark current (V_R = 10 V)	I_R	2 (≤ 30)	nA
Noise equivalent power (V_R = 10 V)	NEP	4.2×10^{-14}	$\frac{W}{\sqrt{Hz}}$
Detection limit	D^*	6.6×10^{12}	$\frac{cm\sqrt{Hz}}{W}$

[1] The spectral sensitivity indicated refers to unfiltered radiation of a tungsten filament lamp at a color temperature of 2856 K (standard light A), in accordance with DIN 5033 and IEC Publ. 306-1).

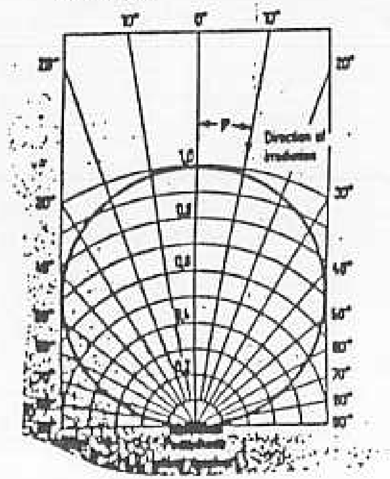
Relative spectral sensitivity versus wavelength



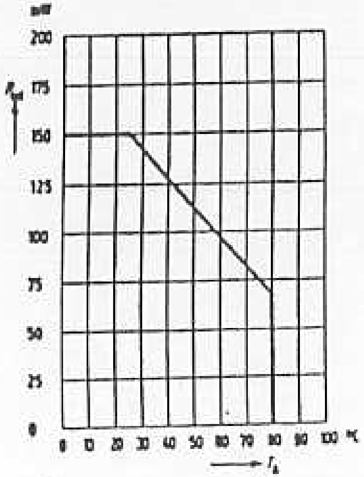
Photocurrent versus illuminance



Directional characteristic
Relative spectral sensitivity versus half angle

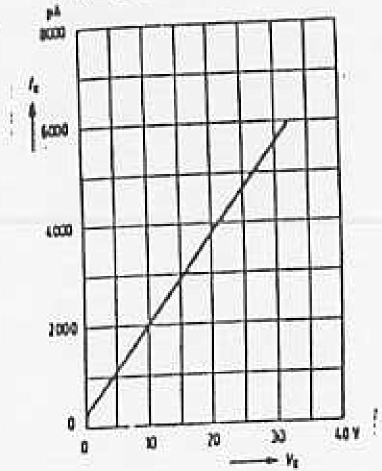


Total power dissipation versus ambient temperature

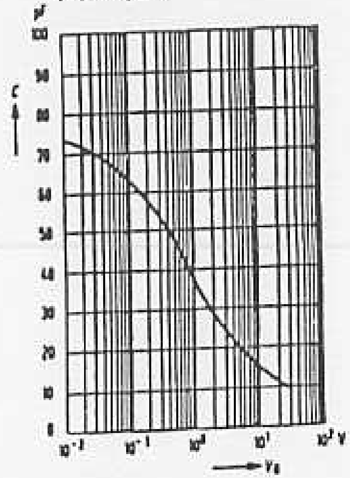


BPW 34

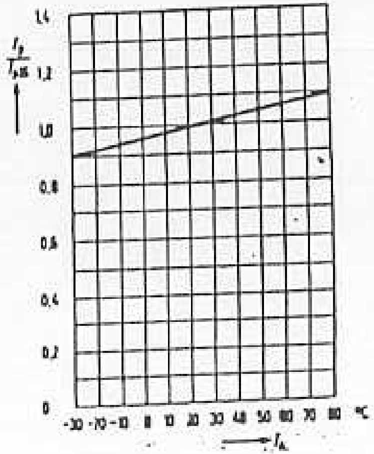
Dark current versus reverse voltage
T_A = 25 °C; E = 0



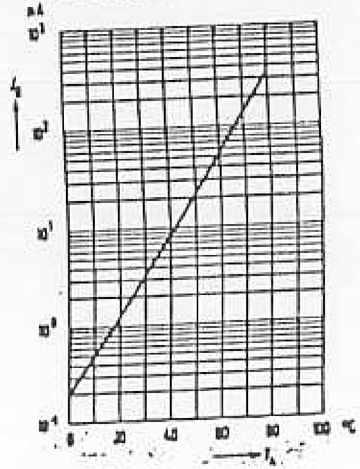
Capacitance versus reverse voltage
f = 1 MHz; E = 0



Photocurrent versus ambient temperature



Dark current versus ambient temperature
V_R = 10 V; E = 0



$I_f = a\Phi + b$ →

$I_f = b\Phi^c$ ($c = 1 \Rightarrow$ linear)

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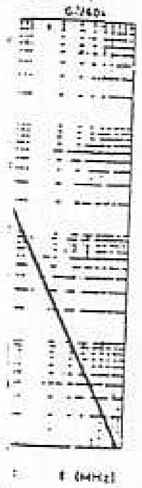
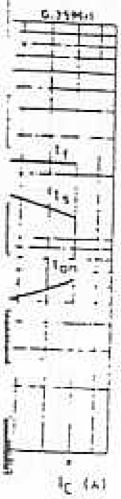




SGS-THOMSON MICROELECTRONICS

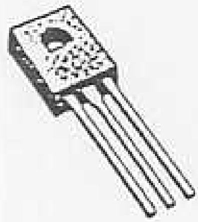
MEDIUM POWER LINEAR AND SWITCHING APPLICATION

DESCRIPTION

The BD433, BD435 and BD437 are silicon epitaxial-base NPN power transistors in Jedec TO-126 plastic package, intended for use in medium power linear and switching applications.

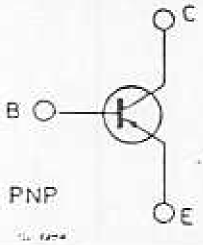
The BD433 is especially suitable for use in car-radio output stages.

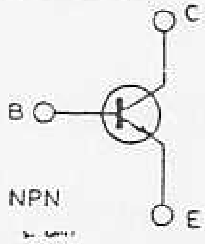
The complementary PNP types are the BD434, BD436 and BD438 respectively.



TO-126 (SOT-32)

INTERNAL SCHEMATIC DIAGRAMS





ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter NPN / PNP*	BD433 / BD434	BD435 / BD436	BD437 / BD438	Unit
V_{CBO}	Collector-base Voltage (I_E = 0)	22	32	45	V
V_{CES}	Collector-emitter Voltage (V_{BE} = 0)	22	32	45	V
V_{CEO}	Collector-emitter Voltage (I_B = 0)	22	32	45	V
V_{EBO}	Emitter-base Voltage (I_C = 0)	5			V
I_C	Collector Current	4			A
I_{CM}	Collector Peak Current (t ≤ 10 ms)	7			A
I_B	Base Current	1			A
P_{tot}	Total Power Dissipation at T_{case} ≤ 25 °C	36			W
T_{stg}	Storage Temperature	– 65 to 150			°C
T_j	Junction Temperature	150			°C

* For PNP types voltage and current values are negative

THERMAL DATA

$R_{th\ j-case}$	Thermal Resistance Junction-case	Max	3.5	°C/W
$R_{th\ j-amb}$	Thermal Resistance Junction-ambient	Max	100	°C/W

ELECTRICAL CHARACTERISTICS (T_{case} = 25 °C unless otherwise specified)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
I_{CBO}	Collector Cutoff Current (I_E = 0)	for BD433/34	V_{CB} = 22 V			100	µA
		for BD435/36	V_{CB} = 32 V			100	µA
		for BD437/38	V_{CB} = 45 V			100	µA
I_{CES}	Collector Cutoff Current (V_{BE} = 0)	for BD433/34	V_{CE} = 22 V			100	µA
		for BD435/36	V_{CE} = 32 V			100	µA
		for BD437/38	V_{CE} = 45 V			100	µA
I_{EBO}	Emitter Cutoff Current (I_C = 0)	V_{EB} = 5 V				1	mA
$V_{CEO(sus)}$*	Collector-emitter Sustaining Voltage (I_B = 0)	I_C = 100 mA	for BD433/34	22			V
			for BD435/36	32			V
			for BD437/38	45			V
$V_{CE(sat)}$*	Collector-emitter Saturation Voltage	I_C = 2 A	I_B = 0.2 A				
			for BD433/34		0.2	0.5	V
			for BD435/36		0.2	0.5	V
			for BD437/38		0.2	0.6	V
V_{BE}*	Base-emitter Voltage	I_C = 10 mA	V_{CE} = 5 V		0.58		V
		I_C = 2 A	V_{CE} = 1 V				
			for BD433/34			1.1	V
			for BD435/36			1.1	V
			for BD437/38			1.2	V
h_{FE}*	DC Current Gain	I_C = 10 mA	V_{CE} = 5 V				
			for BD433/34	40	130		
			for BD435/36	40	130		
			for BD437/38	30	130		
		I_C = 500 mA	V_{CE} = 1 V	85	140		
		I_C = 2 A	V_{CE} = 1 V				
			for BD433/34	50			
			for BD435/36	50			
			for BD437/38	40			
h_{FE1}/h_{FE2}*	Matched Pair	I_C = 500 mA	V_{CE} = 1 V			1.4	
f_T	Transition Frequency	I_C = 250 mA	V_{CE} = 1 V	3			MHz

* Pulsed : pulse duration = 300 µs, duty cycle = 1.5 %.
For PNP types voltage and current values are negative.

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