Introduction to Sensors

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Winter 2010

Mechantronic Systems

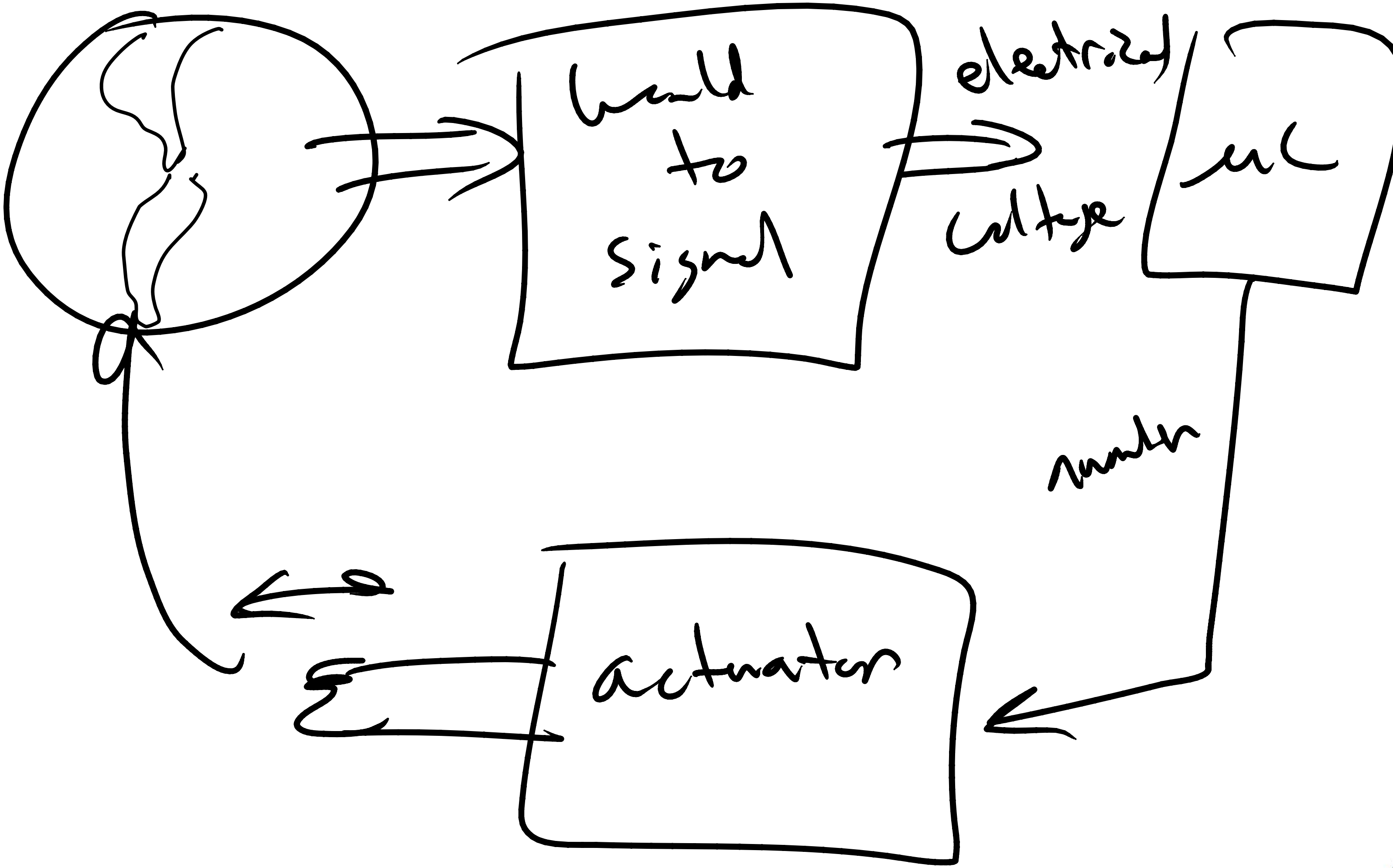
Sensor – powered
transducer – unpowered
) we treat as same

Converts physical phenomena to another signal we can use

Signal conditioning

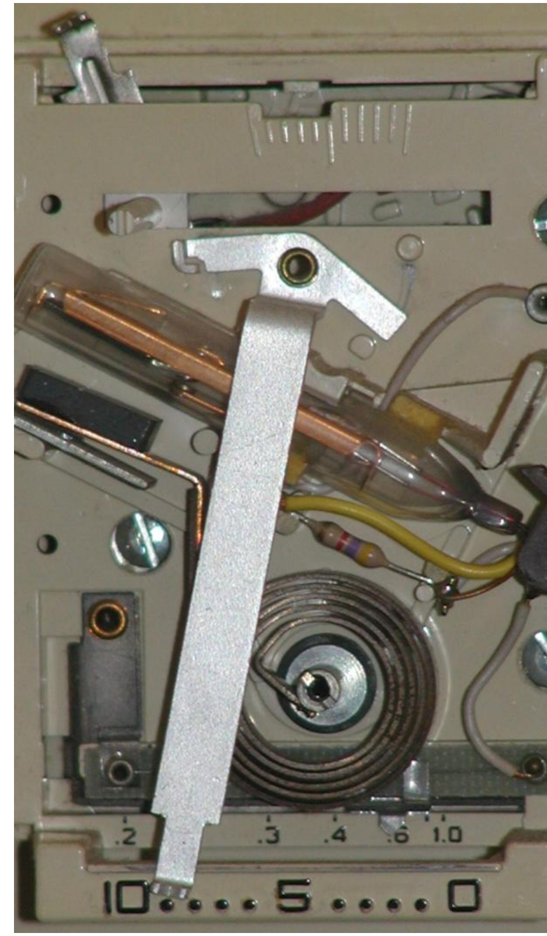
1) noise
2) match sensor to our uC

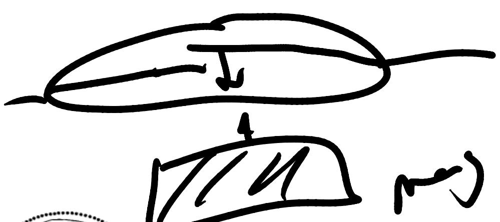
World to Signal

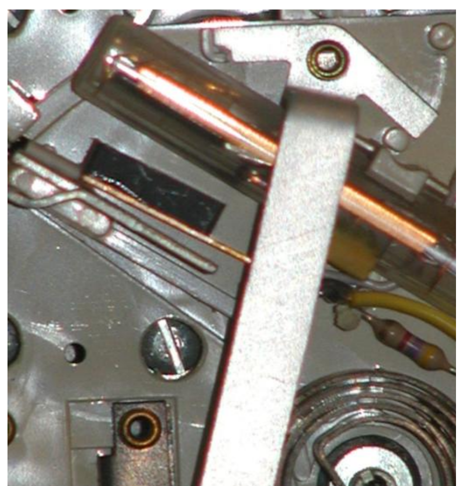


Thermostat

Reed

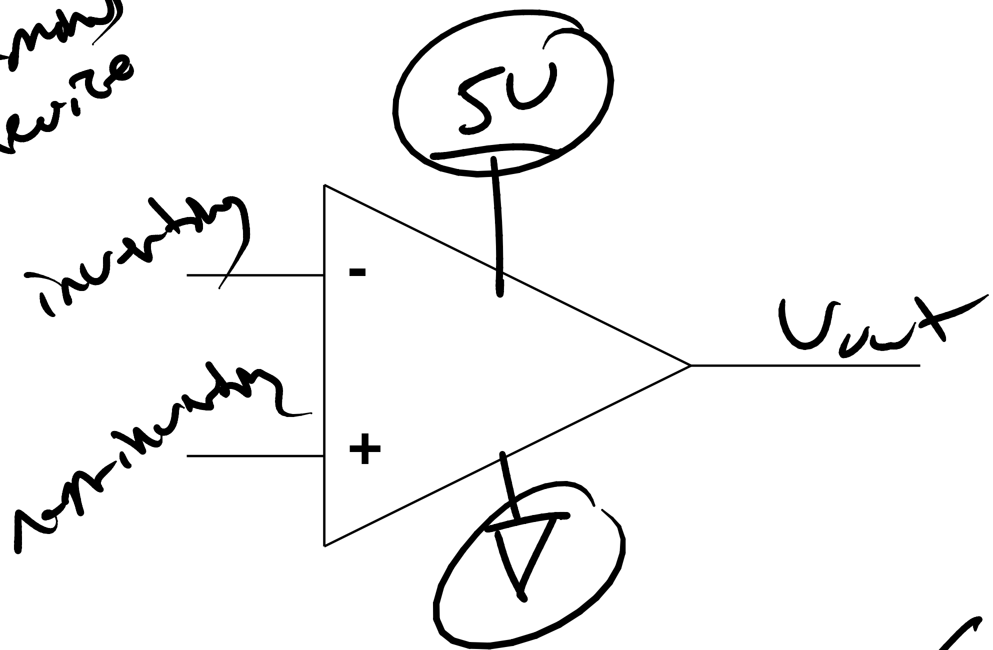






The Operational Amplifier

5 terminal device



"ideal op-amp"

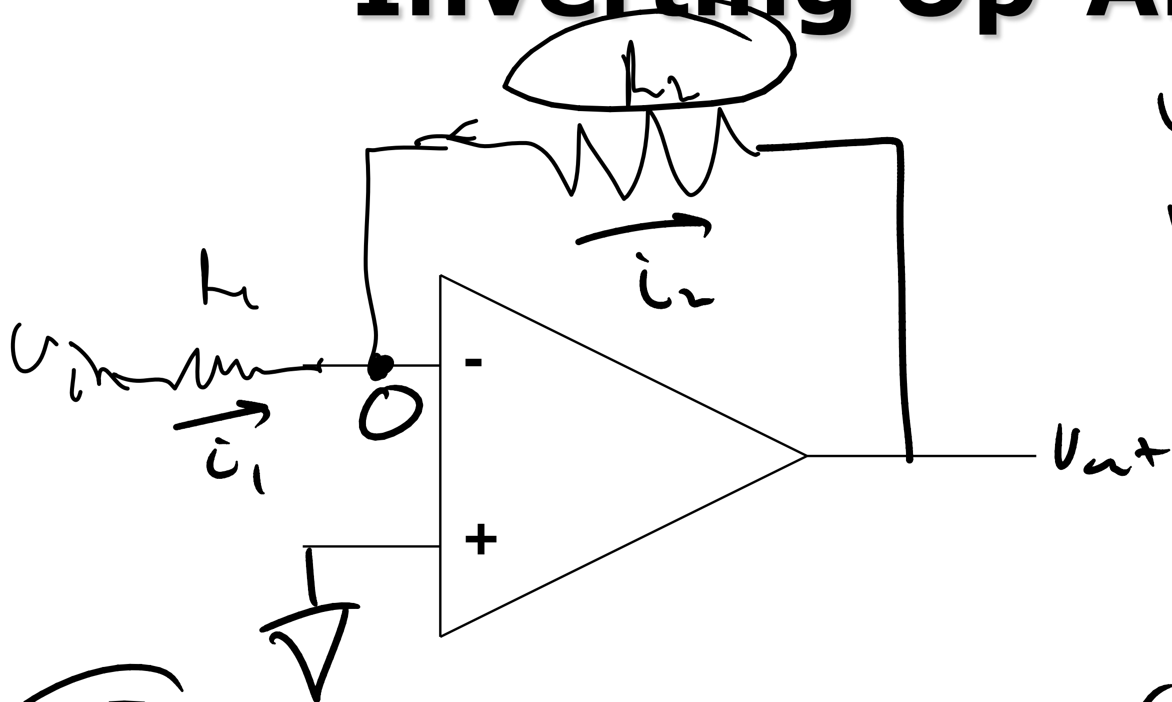
$V_{out} = G(V_+ - V_-)$

Ideal! $G = \infty$ (~100,000)

$V_+ > V_-$ $V_{out} \uparrow$

$V_+ < V_-$ $V_{out} \downarrow$

Inverting Op-Amp



$$V_- = V_+$$

$$\frac{V_{out}}{V_{in}} = \frac{-R_2}{R_1}$$

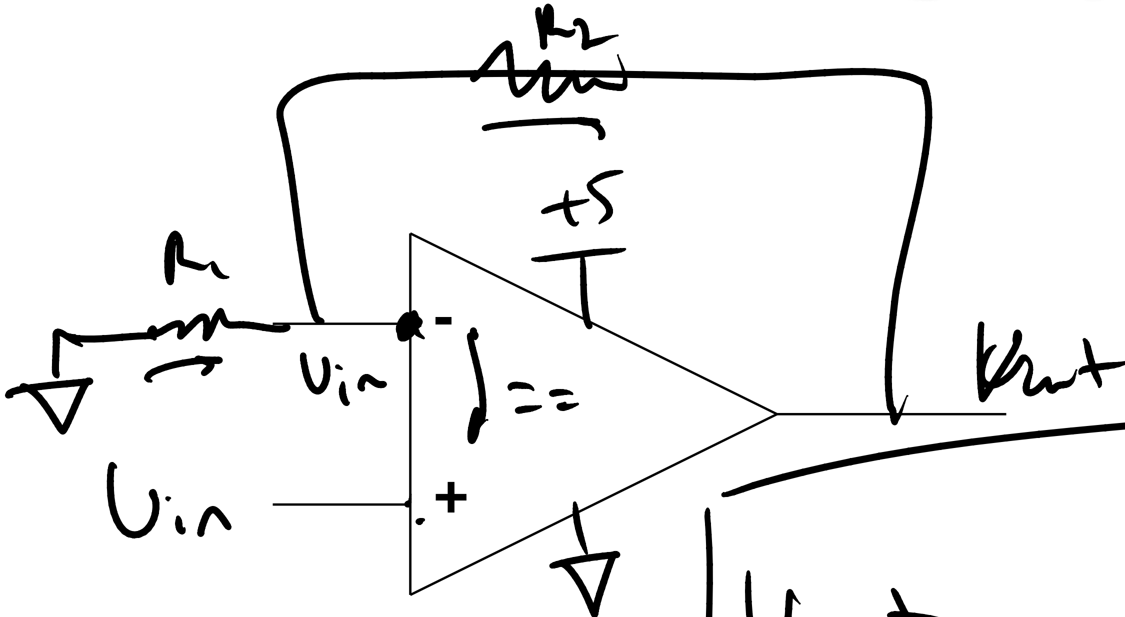
Ohm's Law

$$i_1 = \frac{V_{in} - 0}{R_1} \qquad i_2 = \frac{0 - V_{out}}{R_2}$$

KCL

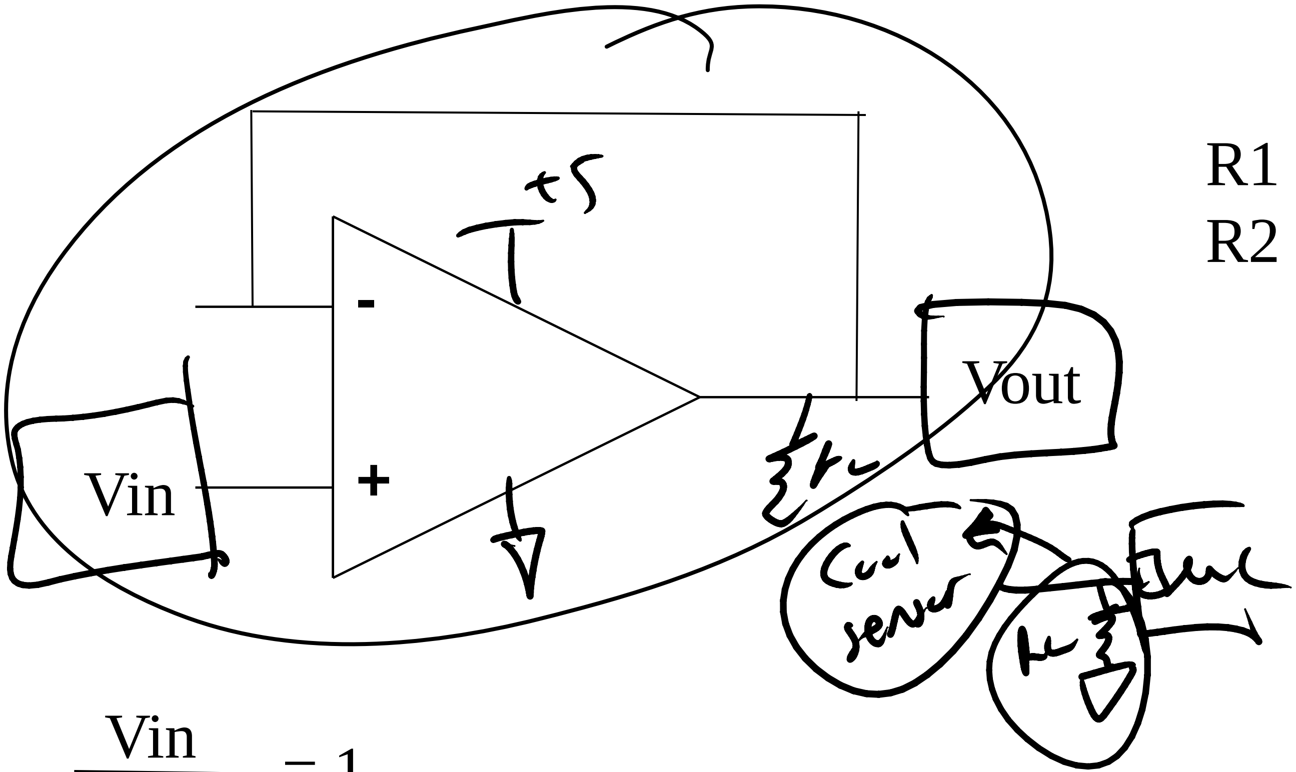
$$\frac{V_{in} - 0}{R_1} = \frac{0 - V_{out}}{R_2} \Rightarrow \frac{V_{in}}{R_1} = \frac{-V_{out}}{R_2}$$

Non-Inverting Op-Amp



$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_2}{R_1}\right)$$

Buffer/Follower Mode

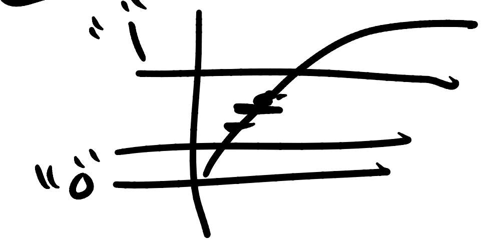


R1 = infinity
R2 = 0

$$\frac{Vin}{Vout} = 1$$

What can the Microcontroller Measure?

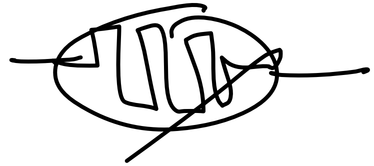
* Voltage
  * ADC
  * high/low

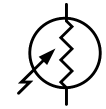


* Time
  * Counters/time
  * NOP = #cycles / clk freq

Basic Sensors: Light

photo cell

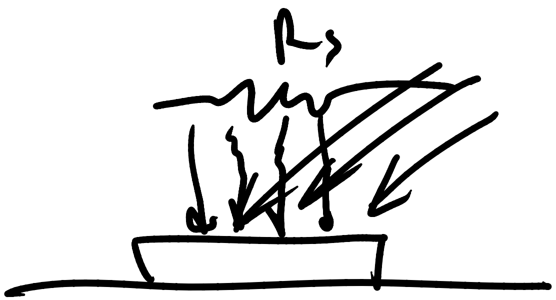




CdS -

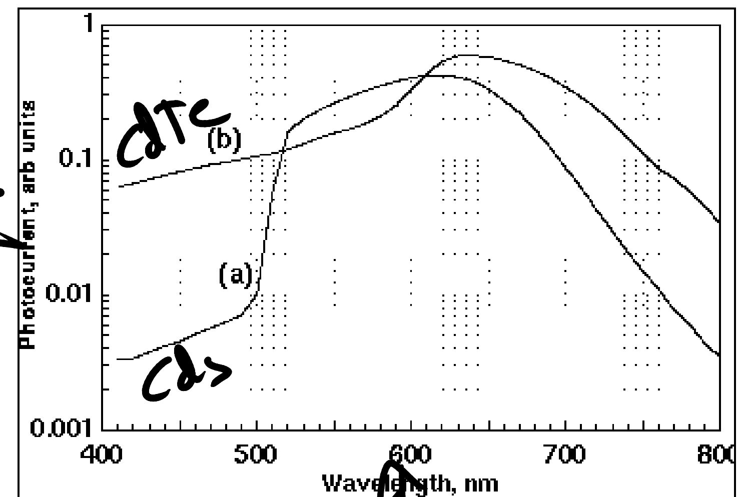
Spectral response

- human range



dynamic response

10's msecs



power rating

hot - drift

malfunction - burn out

CdS Photocell Spec.'s

HAMAMATSU Components Detectors and Light Sources

Opto-semiconductors: CdS Photoconductive Cells

These cells have a spectral response close to the human eye.

Type No.	Package (mm)		Peak Sensitivity Wavelength λp (nm)	Resistance 10 lx *2 Min. Max. (kΩ)	Resistance 0 lx *3 Min. (MΩ)	*4 γ^{100}_{10}	Rise Time tr 0 to 63 % 10 lx (ms)	Fall Tim tf 100 to 37 10 lx (ms)
P1114-04	Metal	TO-18	570	15 to 45	10	0.80	40	20
P320		ϕ5.5	520	35 to 100	20	0.85	60	20
P559			540	2.9 to 8.5	0.1	0.60	100	140
P930			560	7 to 23	0.5	0.68	60	90
P1465			520	27 to 81	10	0.85		20

*1 : Dual element coating type. Listed data are for one element.

*2 : Measured with a tungsten lamp of 2856K.

*3 : Measured 10 seconds after removal of incident illuminateion of 10/x

*4 : Gamma characteristics between 10lx and 100lx. R_{10}, R_{100} Cell resistance values at 10lx and 100lx. $\gamma^{100}_{10} = \frac{\log(R10/R100)}{\log(100/10)}$ Gamma characteristics variations of 0.10.

0 = 100kΩ

10 = 2.9kΩ

$R_A = R_B \left(\frac{E_B}{E_A}\right)^{\gamma}$

$R_{100} = 2.9 \left(\frac{10}{100}\right)^{.6}$

Gamma

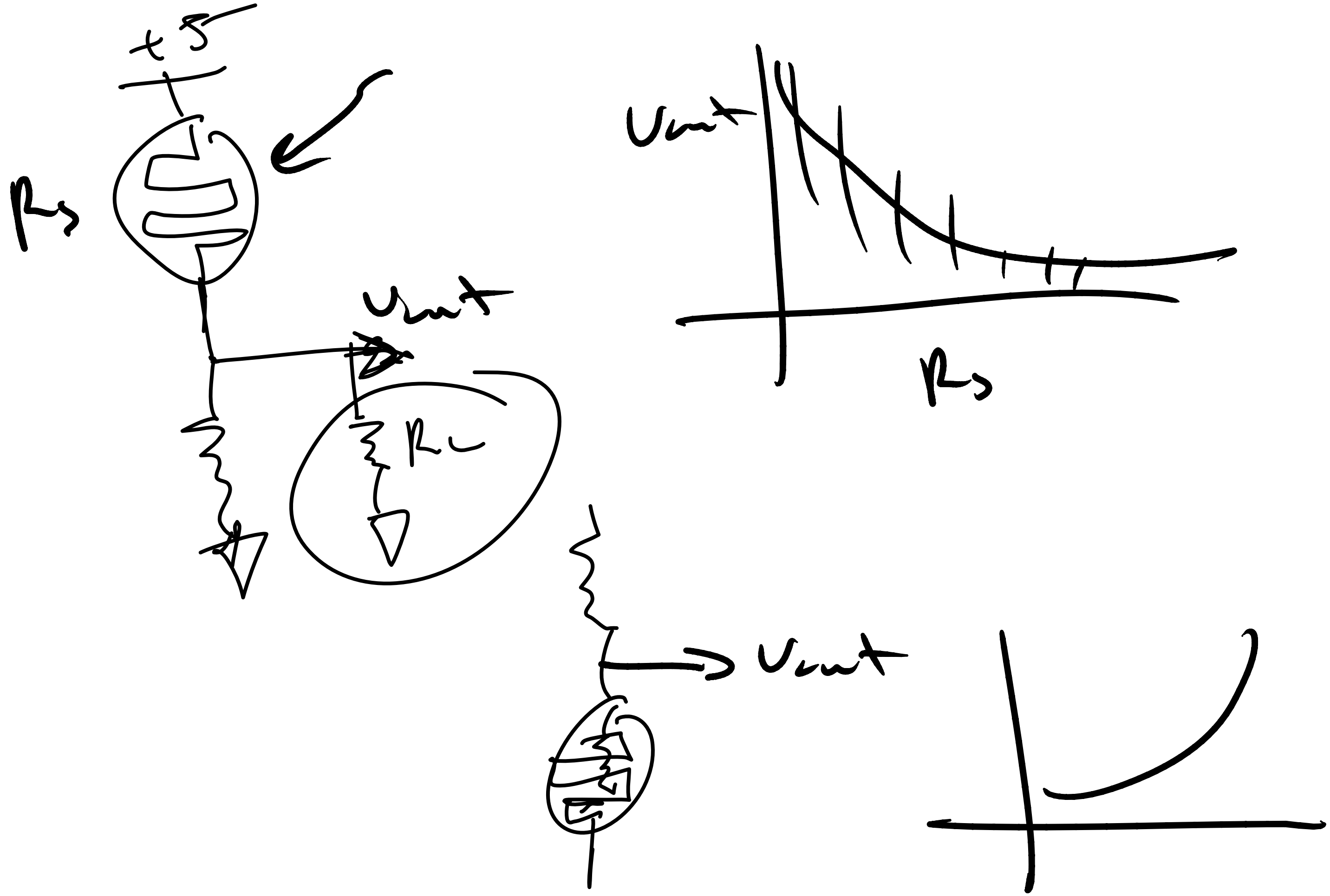
0 lux pure darkness

2-3 dark room

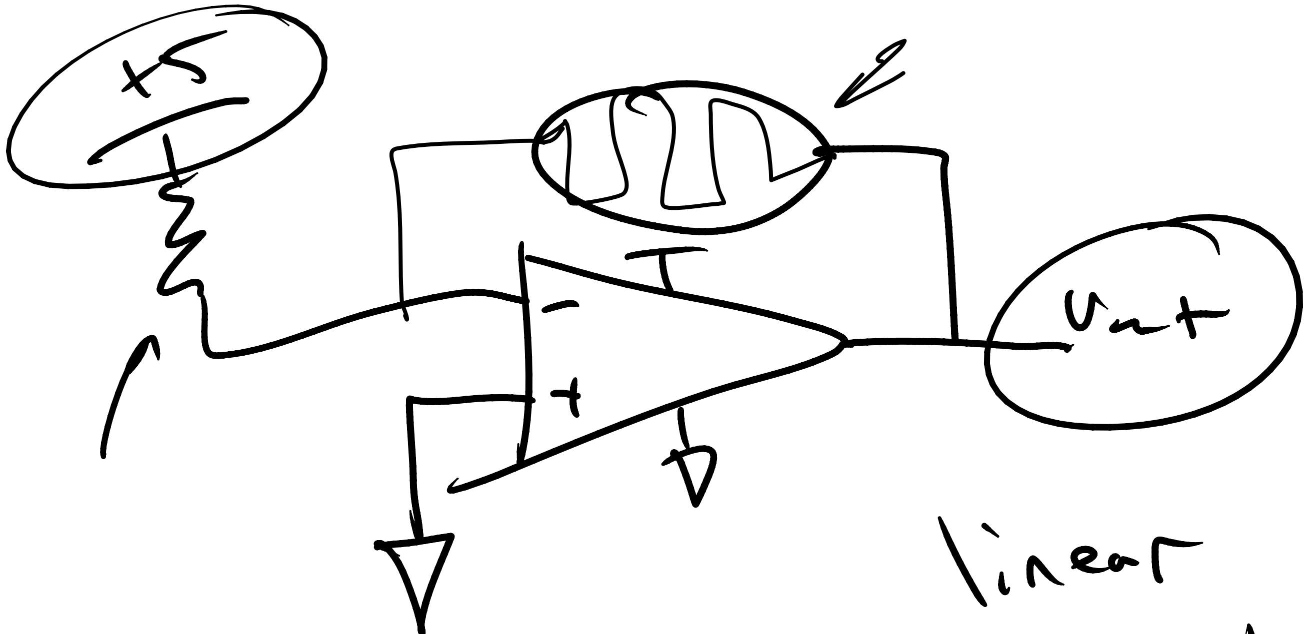
200 Lux office room

1000↑ Lux outside

CdS Photocells: How do you use them?



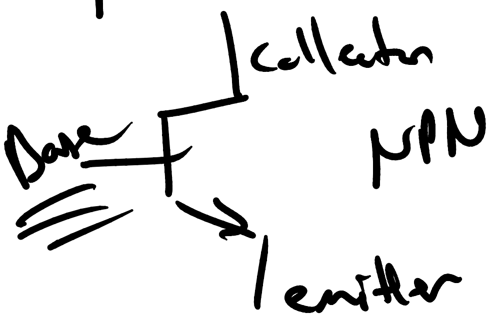
How else could you use a Photocell?

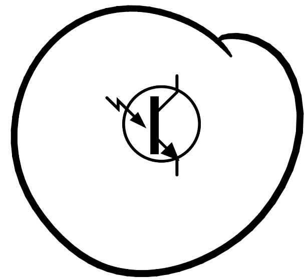


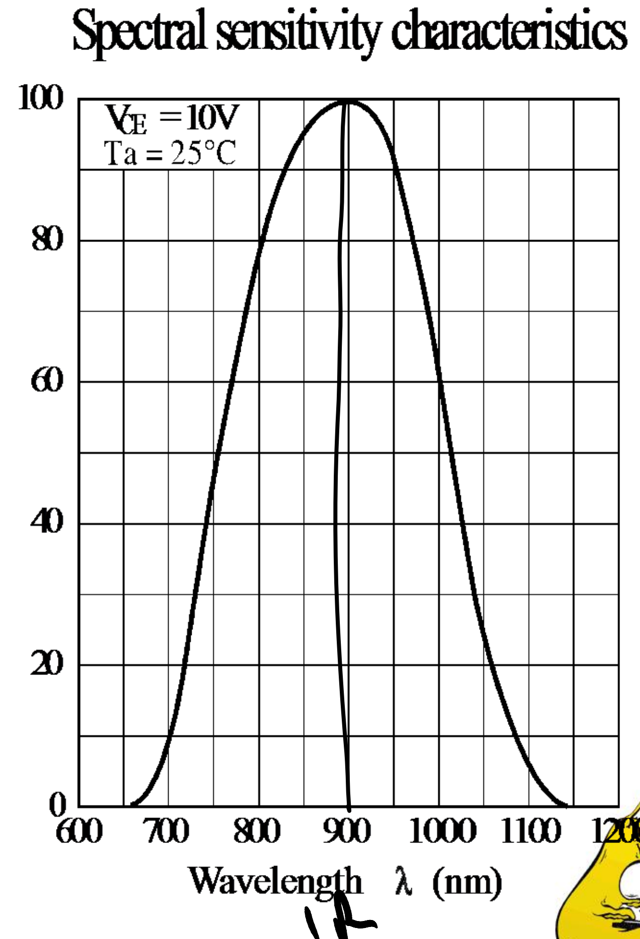
linear output
w/ resistance

Basic Sensors: Light

photo transistor







dynamic response

1-5 μS

Comes with a lens

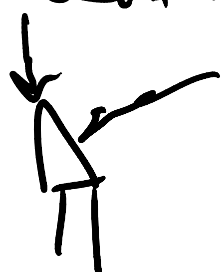
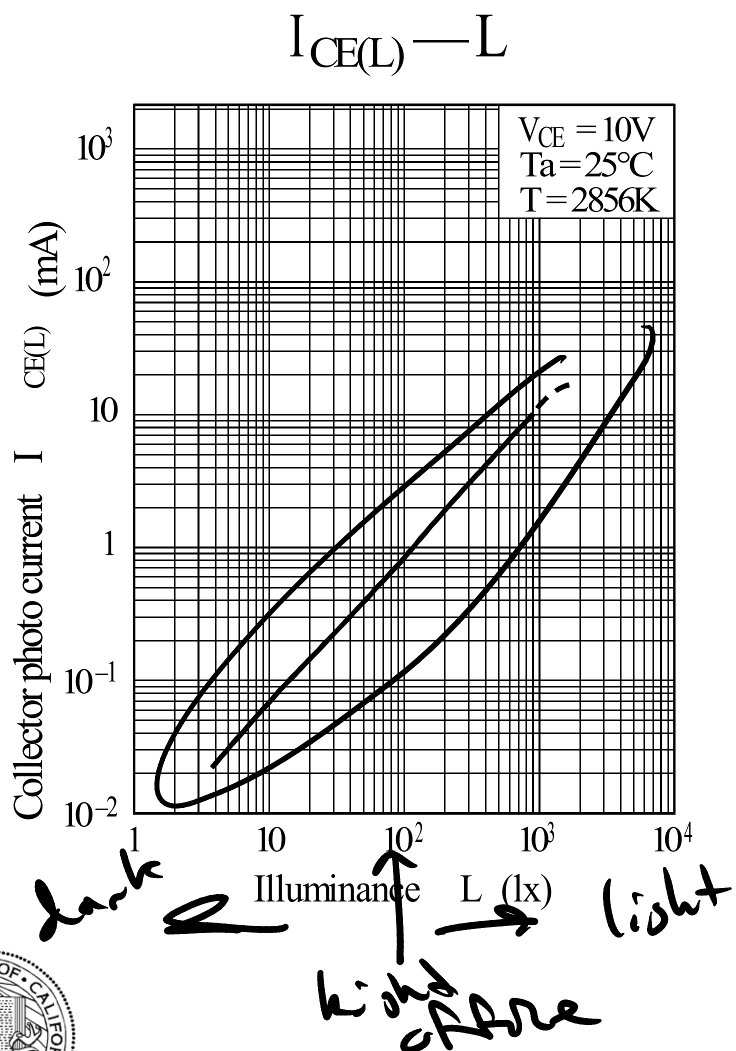
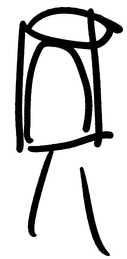
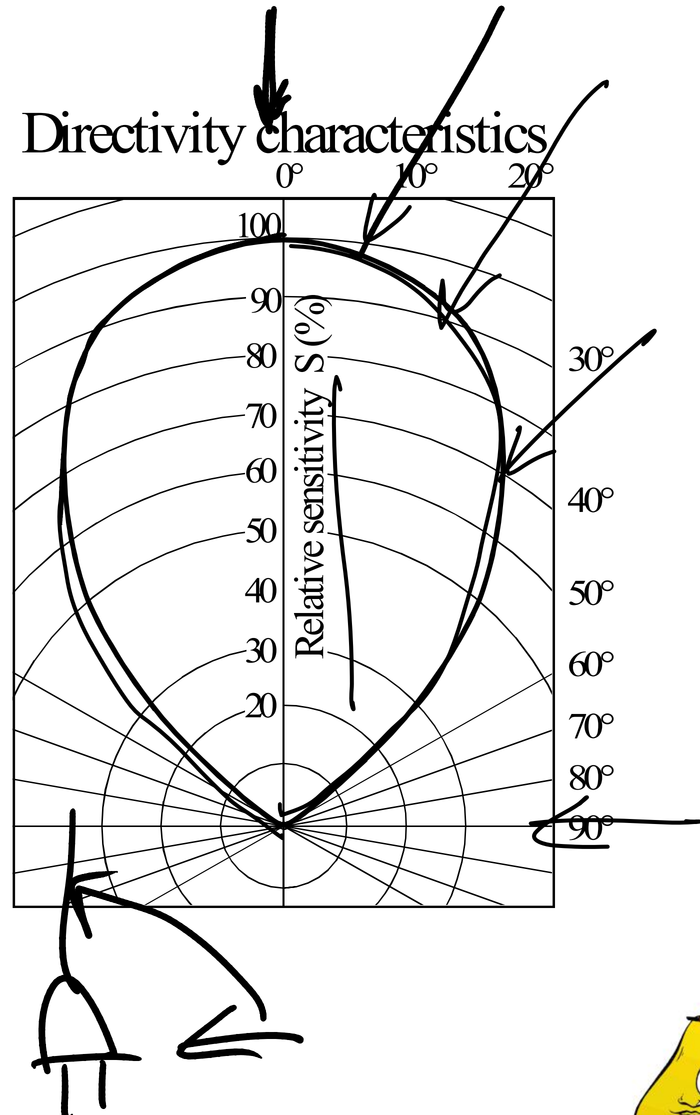


Photo-transistors



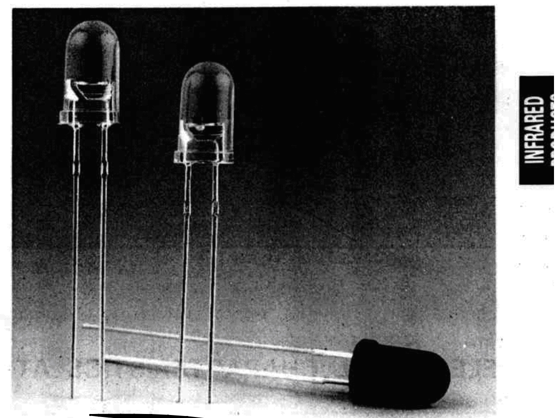




LTR-3208-E Data Sheet (1.2)

FEATURES

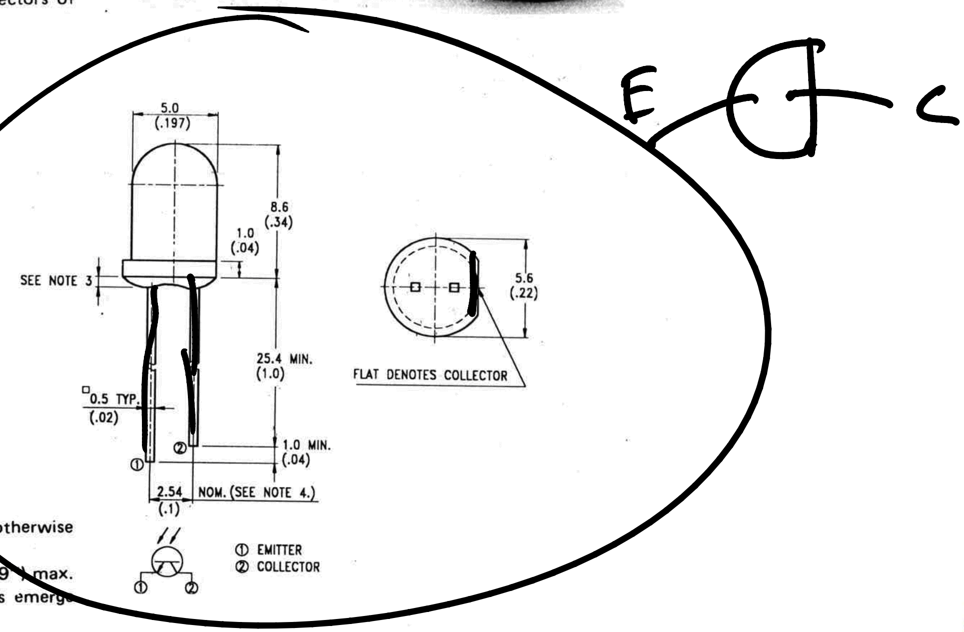
- WIDE RANGE OF COLLECTOR CURRENTS.
- LENSED FOR HIGH SENSITIVITY.
- LOW COST PLASTIC PACKAGE.



DESCRIPTION

The LTR-3208 series consist of a NPN silicon phototransistor mounted in a lensed, clear plastic, end looking package. The lensing effect of the package allows an acceptance half angle of 10° measured from the optical axis to the half power point. This series is mechanically and spectrally matched to the LTE-4208 series of infrared emitting diodes.
The LTR-3208E is a special dark plastic package that cut the visible light and suitable for the detectors of infrared applications.

PACKAGE DIMENSIONS



NOTES:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25mm (.010″) unless otherwise noted.
3. Protruded resin under flange is 1.5mm (.059″) max.
4. Lead spacing is measured where the leads emerge from the package.
5. Specifications are subject to change without notice.

LTR-3208-E Data Sheet (2.2)

ABSOLUTE MAXIMUM RATINGS AT $T_A = 25\,^\circ C$

PARAMETER	MAXIMUM RATING	UNIT
Power Dissipation	100	mW
Collector-Emitter Voltage	30	V
Emitter-Collector Voltage	5	V
Operating Temperature Range	$-55\,^\circ C$ to $+100\,^\circ C$	
Storage Temperature Range	$-55\,^\circ C$ to $+100\,^\circ C$	
Lead Soldering Temperature [1.6mm (0.063in) From Body]	$260\,^\circ C$ for 5 Seconds	

useful

operates

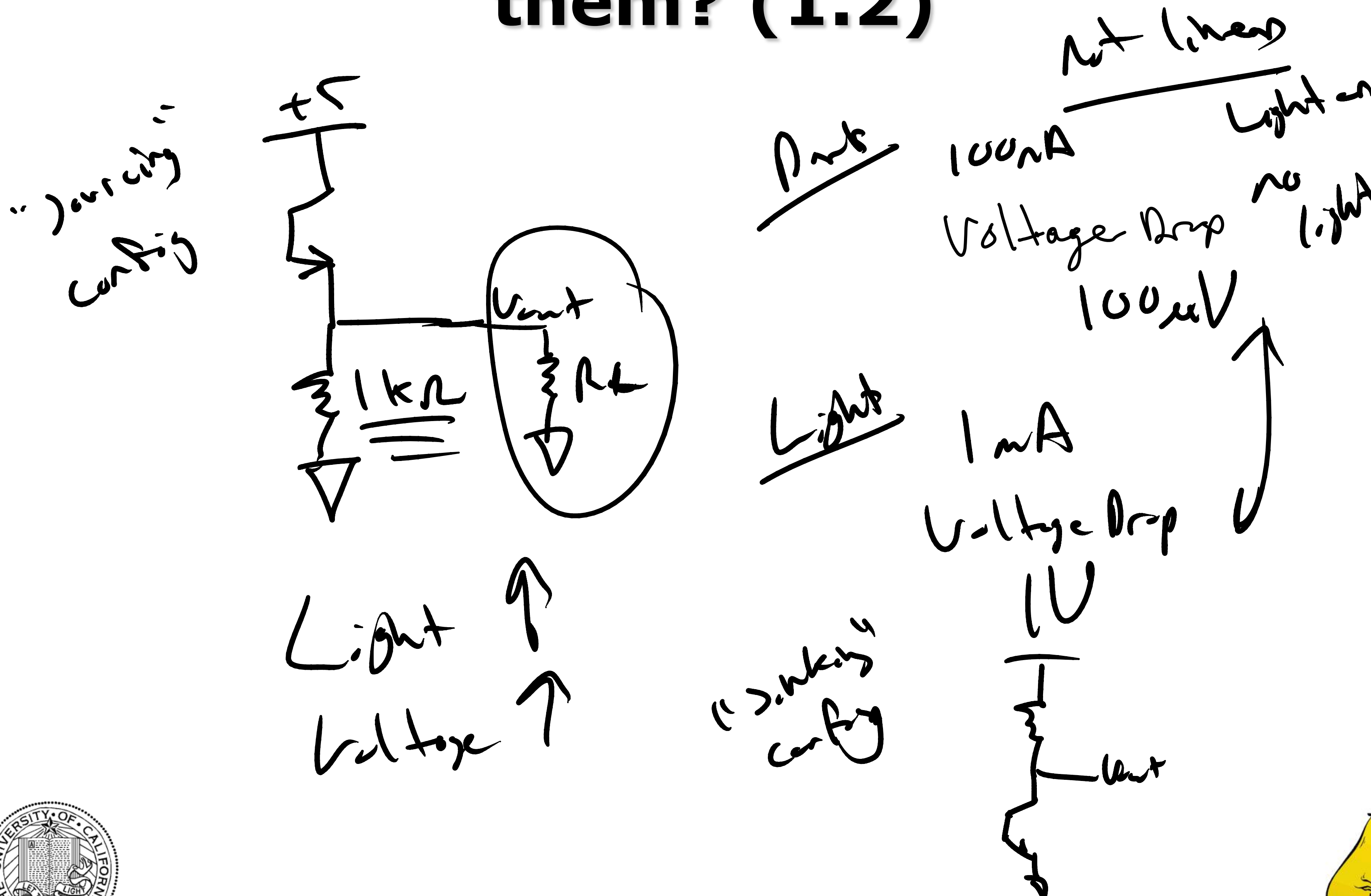
ELECTRICAL CHARACTERISTICS AT $T_A = 25\,^\circ C$

PARAMETER	SYMBOL	PART NO LTR–	MIN	TYP	MAX	UNIT	TEST CONDITION
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$		30			V	$I_C = 1$ mA, $E_e = 0$ mW/cm²
Emitter-Collector Breakdown Voltage	$V_{(BR)ECO}$		5			V	$I_E = 100\ \mu A$, $E_e = 0$ mW/cm²
Collector Emitter Saturation Voltage	$V_{CE(SAT)}$				0.4	V	$I_C = 0.5$ mA, $E_e = 0.5$ mW/cm²
Rise Time	T_r			10		μS	$V_{CC} = 30$ V, $I_C = 800\ \mu A$, $R_L = 1\ k\Omega$
Fall Time	T_f			5		μS	
Collector Dark Current	I_{CEO}				100	nA	$V_{CE} = 10$ V, $E_e = 0$ mW/cm²
On State Collector Current	$I_{C(ON)}$	3208	1	4		mA	$V_{CE} = 5$ V, $E_e = 1$ mW/cm², $\lambda = 940$ nm
		3208E	1	2		mA	

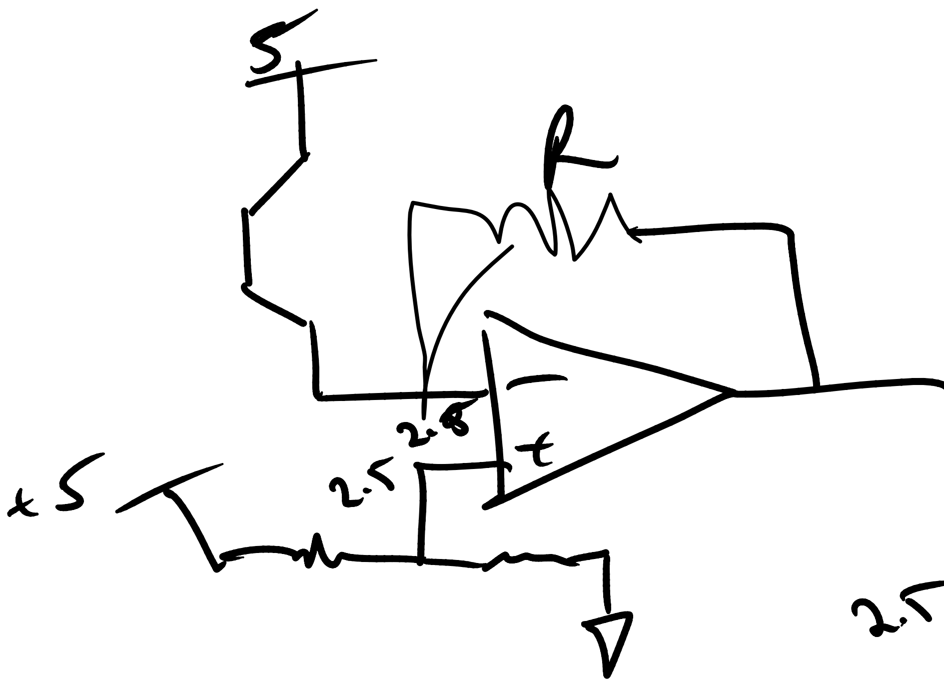
Dark — 100nA

Light — 1-2mA

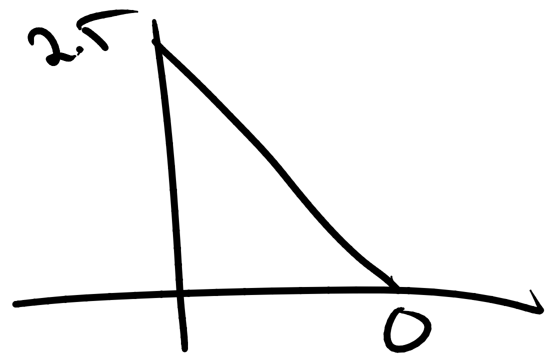
Phototransistors: How do you use them? (1.2)



Phototransistors: How do you use them? (2.2)

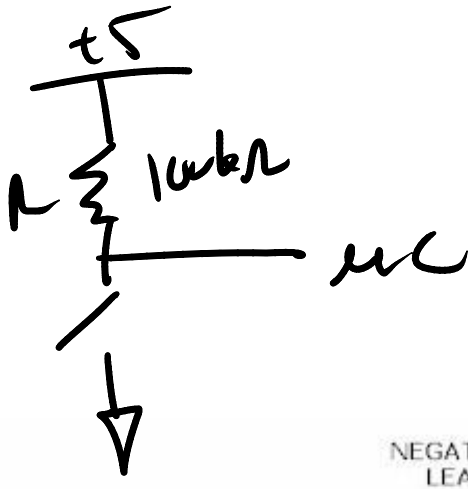


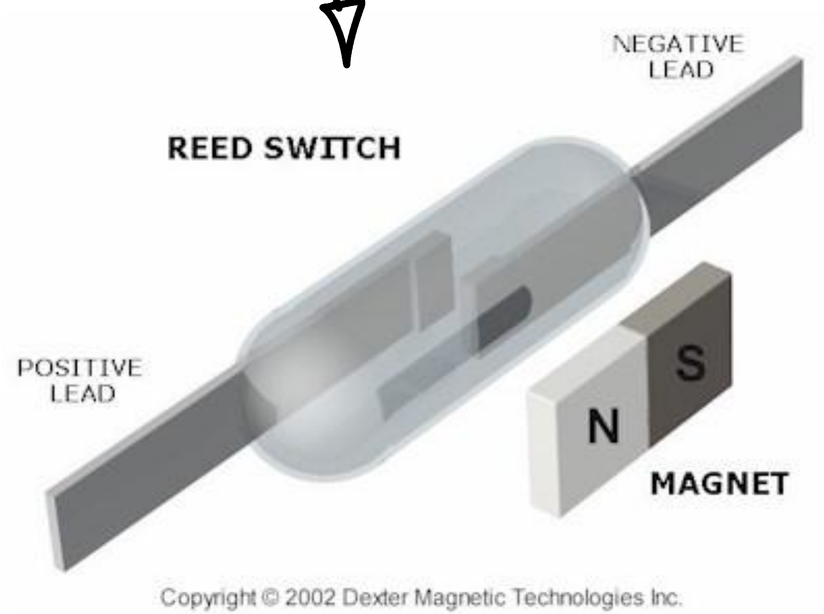
$V_{out} = -i_{ce} * R + 2.5$



linear Response

Basic Sensors: Magnetic Field (1.4)





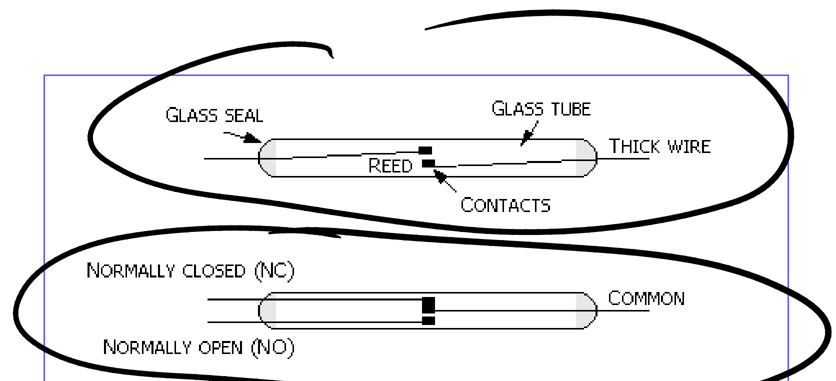


Figure 1: Two-reed (top) and three-reed (bottom) reed switches

Basic Sensors: Magnetic Field (2.4)

Hall effect

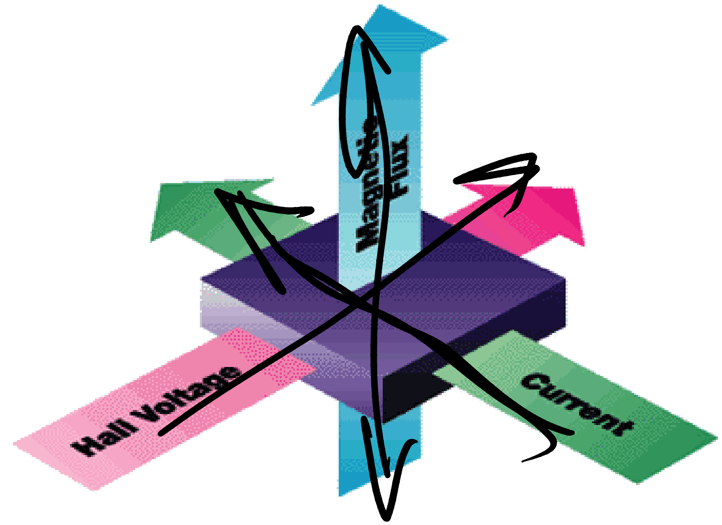
semiconductor device

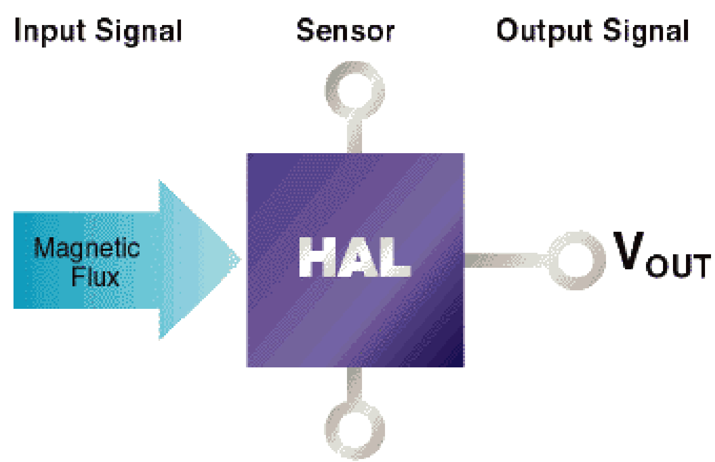
two types

+ On/off switch (Reed)

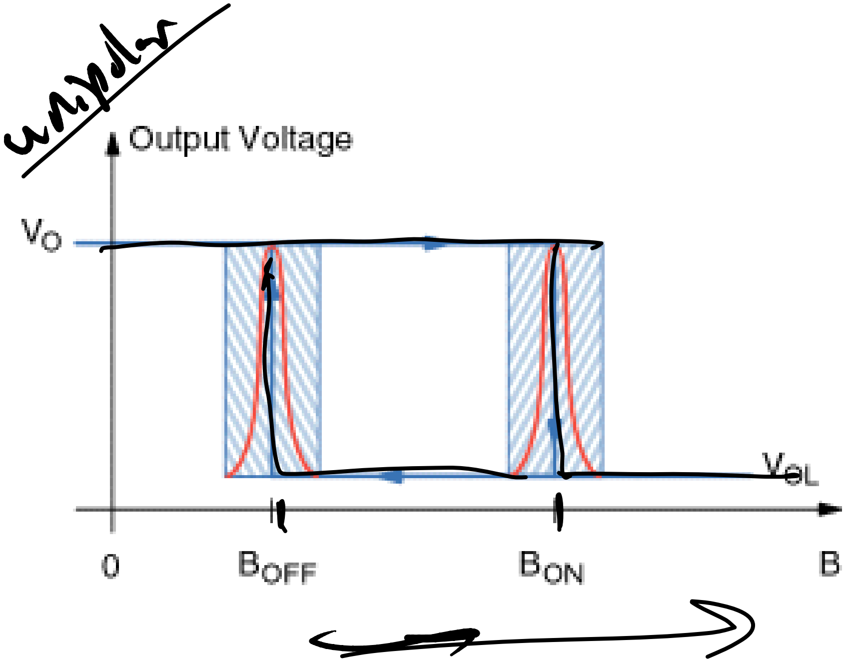
+ analog – 3x5 ...

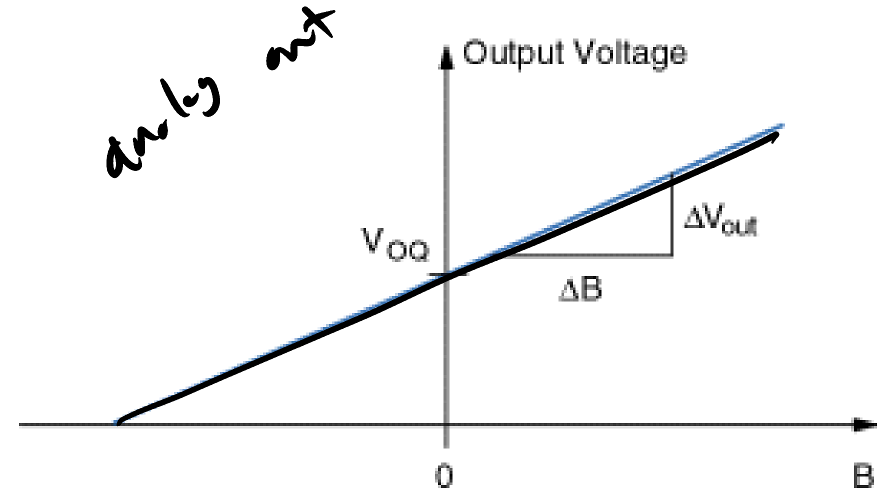
strength of magnetic field

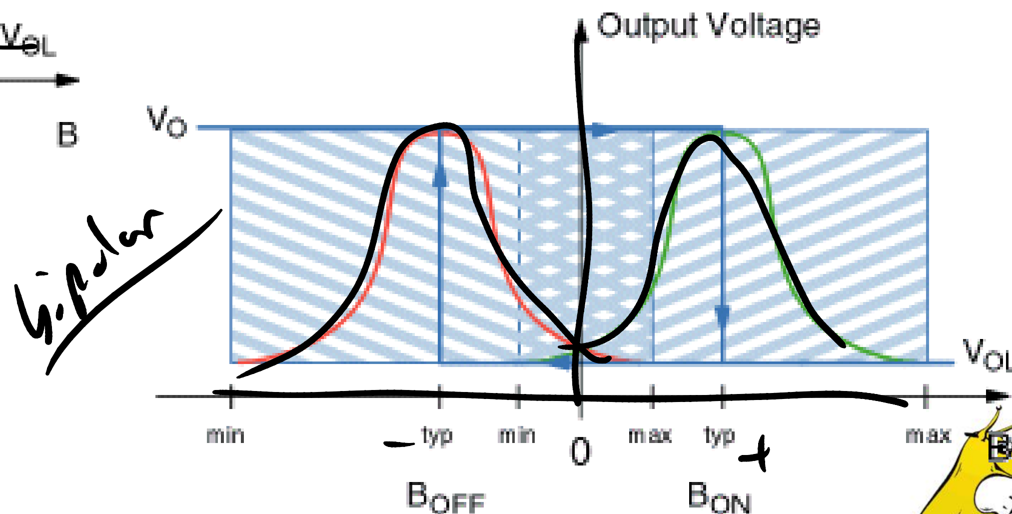




Basic Sensors: Magnetic Field (3.4)

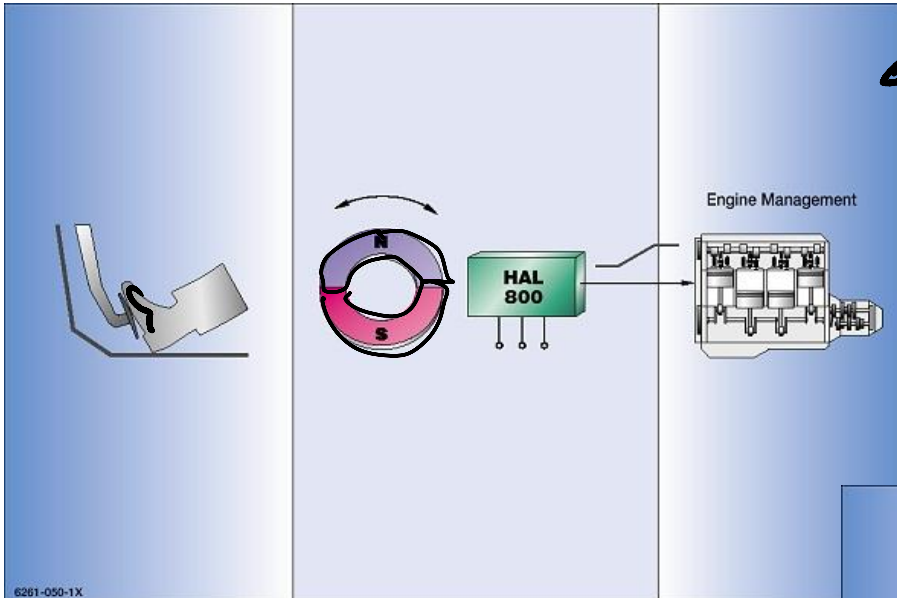






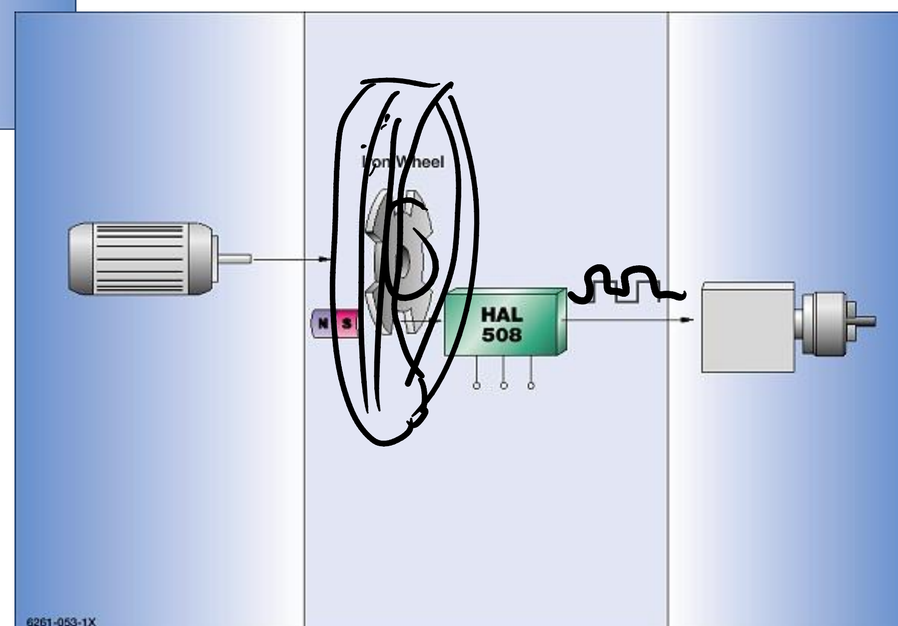
Basic Sensors: Magnetic Field (4.4)

rotation → magnetic field → voltage → engine ctrl.



rotation rate → freq → time base

anti lock breaks



Measuring Position

[translate movement to voltage]

Light < Intensity – IR
LIDAR $$$!= student project

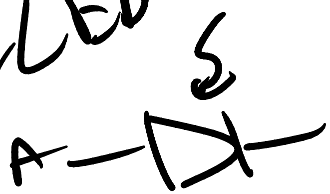
Sound – two way time of flight
ultrasonic 1–2m

Submarines
velocity – motor as a generator
→ ∫ position
[illegible]

accelerometers – kits

Optical Sensors for Position (1.2)

LED



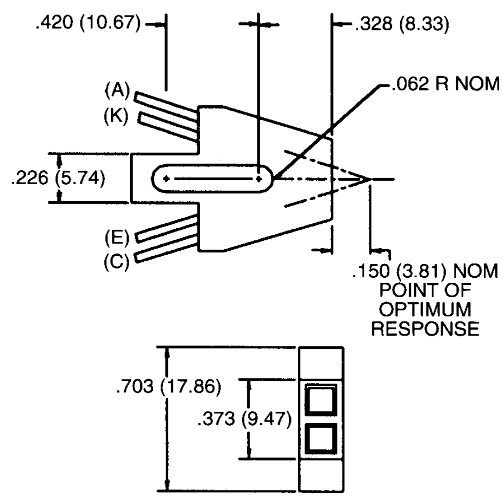
pair with a phototransistor

QT OPTOELECTRONICS

REFLECTIVE OBJECT SENSORS

QRB1113/1114

PACKAGE DIMENSIONS



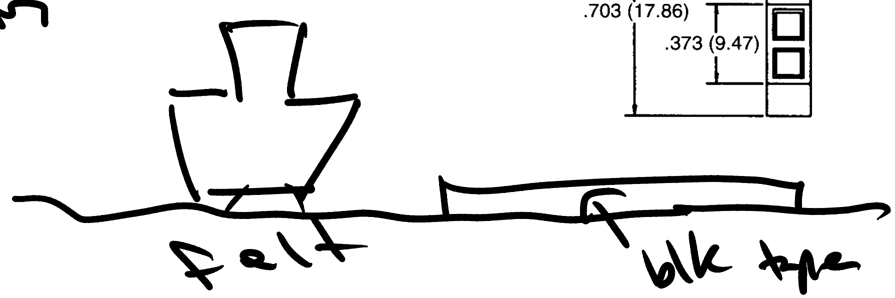
DESCRIPTION

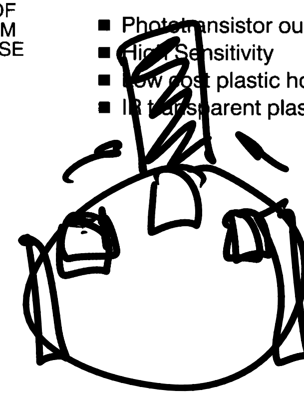
The QRB1113/1114 consists of an infrared emitting diode and an NPN silicon phototransistor mounted side by side on a converging optical axis in a black plastic housing. The phototransistor responds to radiation from the emitting diode only when a reflective object passes within its field of view. The area of the optimum response approximates a circle .200″ in diameter.

FEATURES

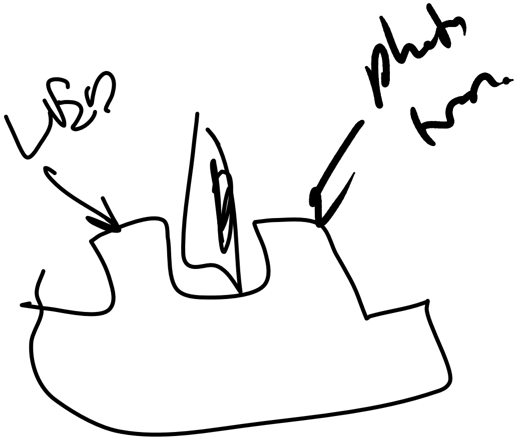
- Phototransistor output
- High Sensitivity
- Low cost plastic housing
- IR transparent plastic covers for dust protection.

tape following





Optical Sensors for Position (2.2)

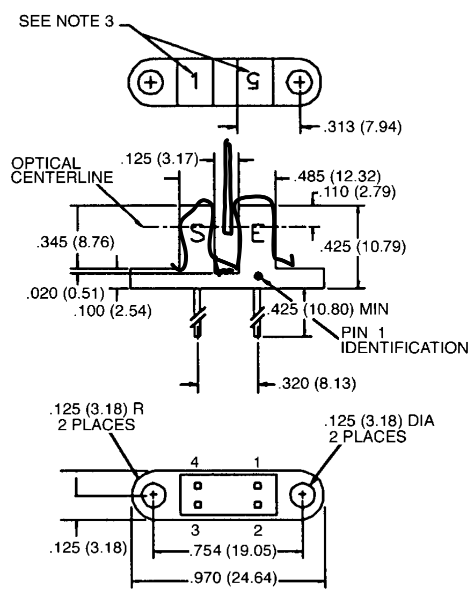


OPTOELECTRONICS

SLOTTED OPTICAL SWITCH

OPB860T11/OPB860T51/OPB860T55

PACKAGE DIMENSIONS



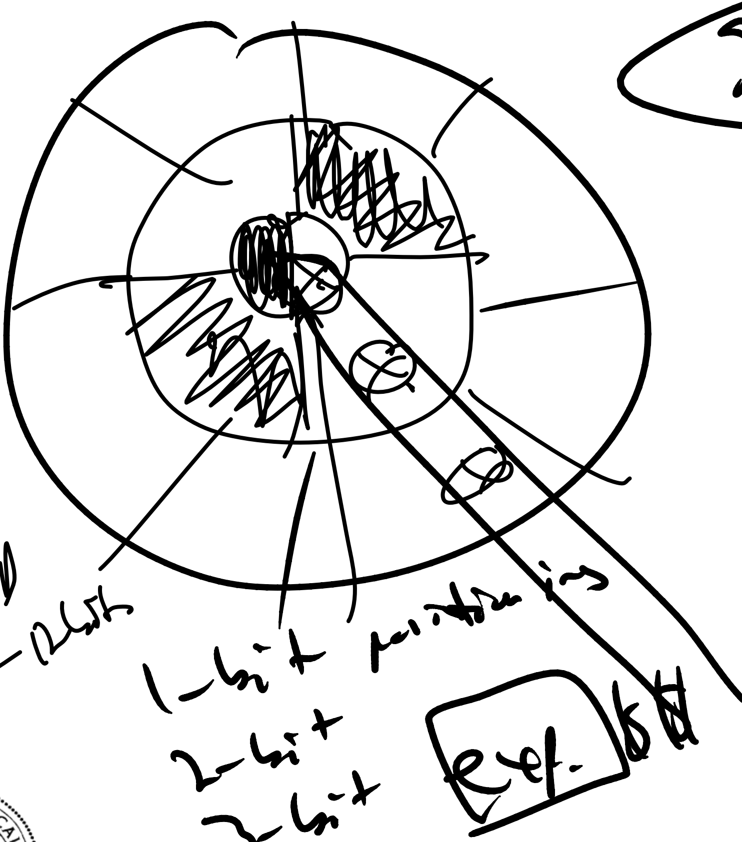
DESCRIPTION

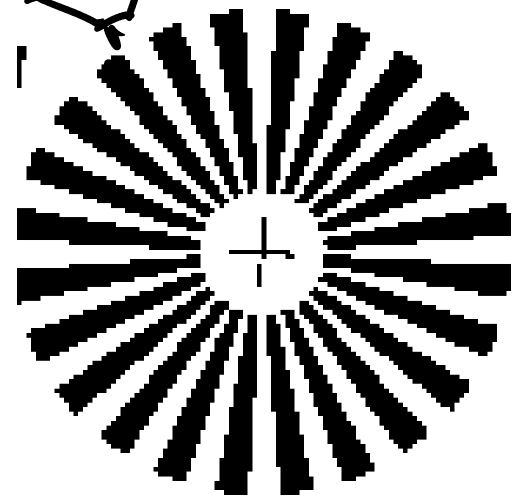
The OPB860T series of switches is designed to allow the user maximum flexibility in applications. Each switch consists of an infrared emitting diode facing an NPN phototransistor across a .125″ (3.18mm) gap. A unique housing design provides a smooth external surface to prevent dust build-up while molded internal apertures give precise positioning and also provide protection from ambient light interference.

FEATURES

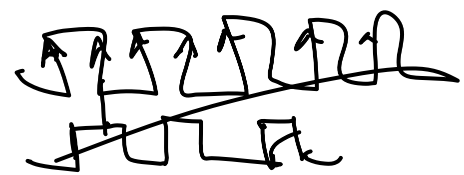
- Fully enclosed design allows dust protection.
- Lead spacing at .320″.
- .050″ and .010″ aperture options.
- PCB mountable.

Encoders for Position Sensing (1.2)



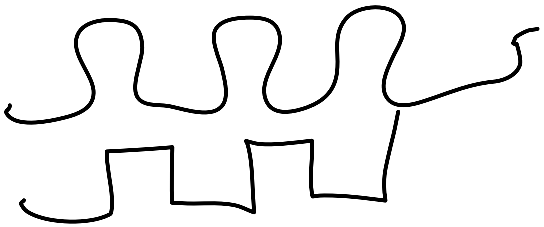


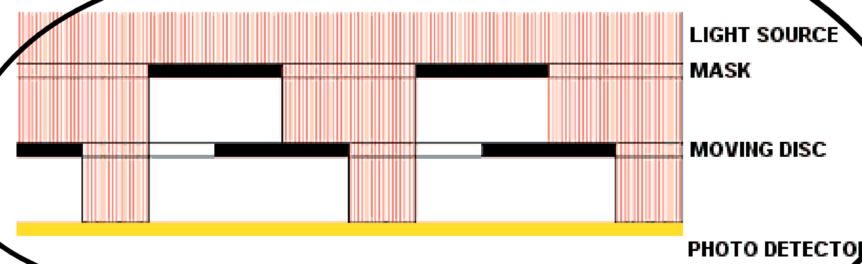
48 segments



Encoders for Position Sensing (2.2)

Q.R.E.





Light
2 sensor

MC
A
B

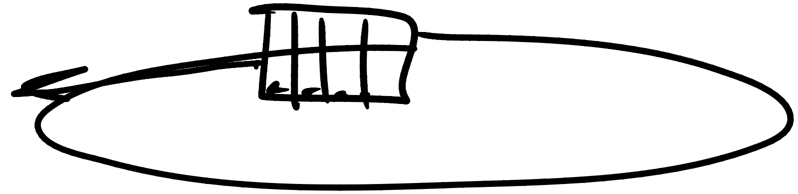
Encoders: Where Do You Find Them?

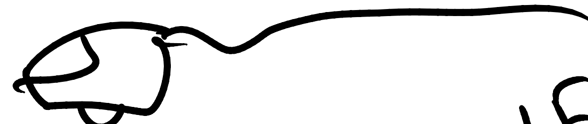
automotive

printers – cheap

old ball mice

hard drives





EVERYWHERE
+ cheap
+ accurate

Basic Sensors: Temperature (1.2)

Thermistor

- very temp dependent resistor

non-linear

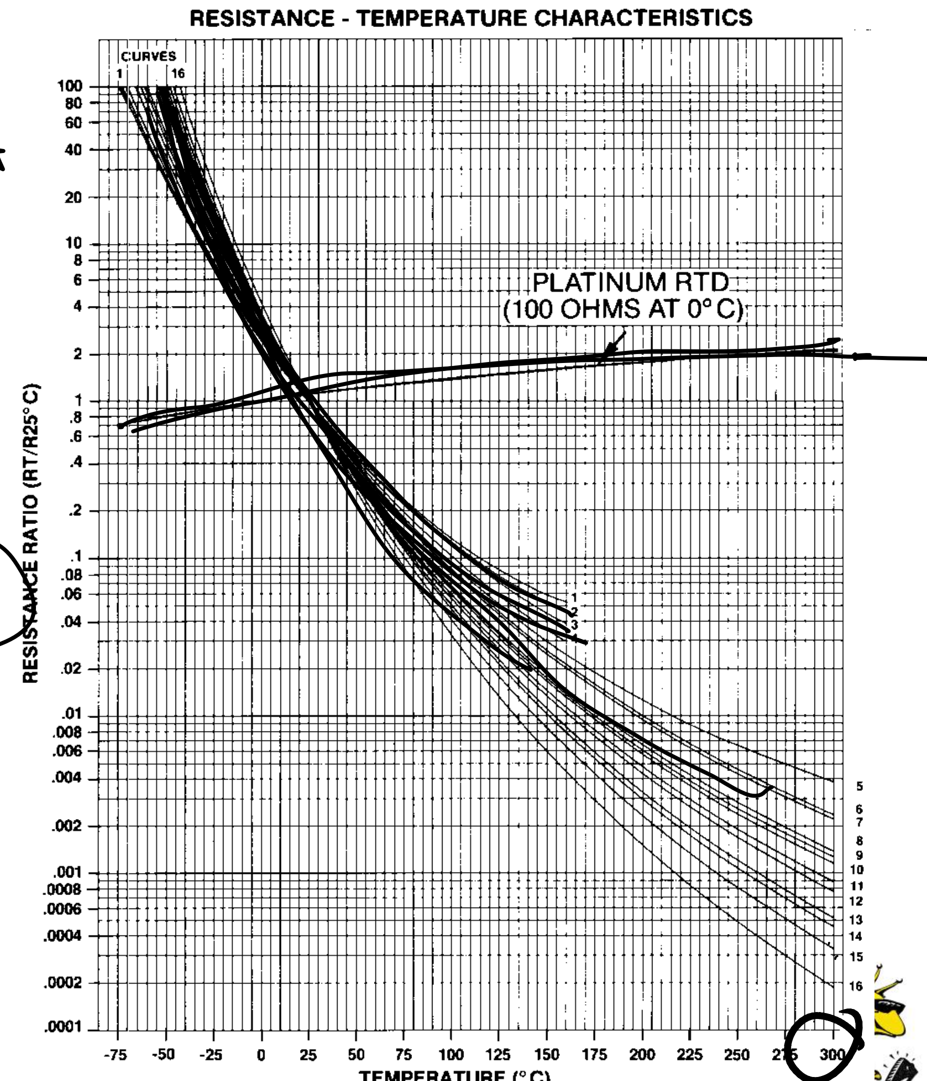
well defined

↑T ↓R

top out 300°C

Large ΔR for ΔT

① A,B,C 3rd order poly.



Basic Sensors: Temperature (2.2)

R.T.D — made out of platinum ≡ $$

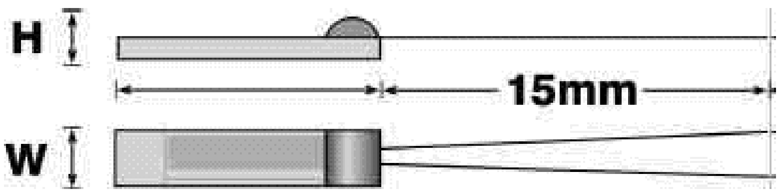
pro
- High temp range
- very linear
- very stable ⟸ repeatable

R ↑
T ↑

cons
- Not as sensitive
  small ΔR for ΔT
- pricey > $20

Sensor Scientific, inc.

PLATINUM THIN FILM RTD ELEMENTS



- AVAILABLE IN 100, 500, 1000, AND 2000 OHM RESISTANCE VALUES
- STANDARD IEC 751, ASTME1137 & NON-STANDARD TOLERANCES AVAILABLE
- WIDE CHOICE OF SIZES
- 2, 3, AND 4 WIRE EXTENSION LEADS AVAILABLE
- CUSTOM-ENGINEERED TEMPERATURE PROBE ASSEMBLIES

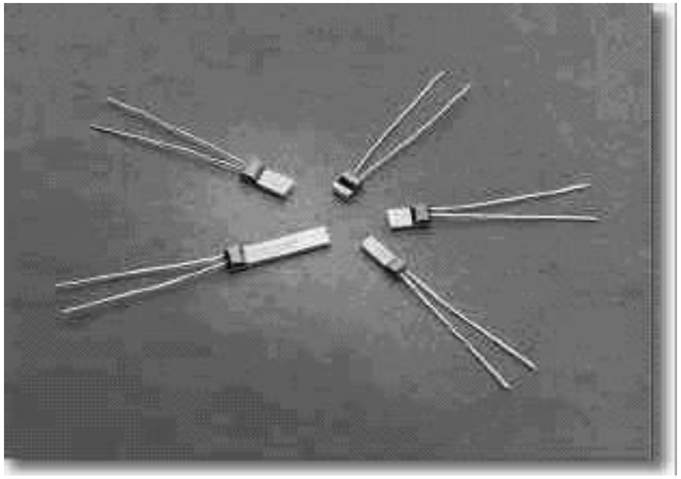
Sensor Scientific, Inc. Platinum Thin Film RTD Elements are fabricated using state-of-the-art thin film processing techniques, resulting in an element of exceptional quality and stability. The wide choice of resistance, tolerance, and size options allows for complete design flexibility.

RTD elements are available with extension leads, and incorporated in complete temperature probe assemblies. Please contact Sensor Scientific for additional information.

Assemblies:
Generally, thin film RTD elements are incorporated into some type of assembly for protection. Extension leads may be attached via soldering, crimping, brazing or welding. The attachment method must be capable of withstanding the intended maximum operating temperature.

The following precautions must be taken when incorporating the element into an assembly.

1) Avoid straining the element leads.
2) If extension leads are attached via soldering or brazing, all flux residue must be removed.
3) The resistance of extension leads must be taken into consideration. Resistance value at 0°C calibrated 1mm from end of lead wire.
4) If elements are encapsulated in a potting compound, insure that the compound will not induce pressure loads, resulting in a strain-gage effect.



Platinum RTD Datasheet

Resistance at 0 Deg. C. ohms	L Length mm	W Width mm	H Height mm	Part Number
100	5.0 +/- 0.2	1.0 +/- 0.2	1.3 +/- 0.2	P01 IIn 1
100	5.0 +/- 0.2	1.5 +/- 0.2	1.3 +/- 0.2	P01 IIn 2
100	2.3 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P01 IIn 3
100	5.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P01 IIn 4
100	10.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P01 IIn 5
100	5.0 +/- 0.2	4.0 +/- 0.2	1.3 +/- 0.2	P01 IIn 6
100	1.6+/- 0.15	1.25 +/- 0.1	1.00 +/- 0.2	P01 II M7
500	5.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P05 IIn 1
500	10.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P05 IIn 2
500	5.0 +/- 0.2	4.0 +/- 0.2	1.3 +/- 0.2	P05 IIn 3
1000	4.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P10 IIn 1
1000	10.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P10 IIn 2
1000	5.0 +/- 0.2	4.0 +/- 0.2	1.3 +/- 0.2	P10 IIn 3
1000	1.6+/- 0.15	1.25 +/- 0.1	1.00 +/- 0.2	P10 II M4
2000	10.0 +/- 0.2	2.0 +/- 0.2	1.3 +/- 0.2	P20 IIn 4

Resistance value at 0°C calibrated 1mm from end of lead wire. DIN = IEC751

II - Tolerance
- 01=1/10 DIN B at 0°C
- 02 = 1/5 DIN B at 0°C
- 03 = 1/4 DIN B at 0°C
- 04 = 1/3 DIN B at 0°C
- 0A = 1/2 DIN B (DIN A) at 0°C
- 0B = DIN B
- 05 = ASTM B
- 06 = 3/2 DIN B at 0°C
- 07 = 2 DIN B at 0°C
- 08 = 5 DIN B at 0°C
- 09 = 10 DIN B at 0°C

n - Temperature Range
- L = -50 to + 400 Deg C
- M= -50 to + 550 Deg C
- H= -50 to + 600 Deg C

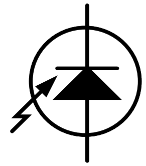
$\Delta R \propto R$ @ 0°C

$R_T = \left(\frac{T}{0^\circ}\right) R_0$

absolute temp

Basic Sensors: Light (1.2)

photo diode



Silica device
near IR

Rapt 5-10 nsec

used in communications

Light sensitivity less than photo transistor

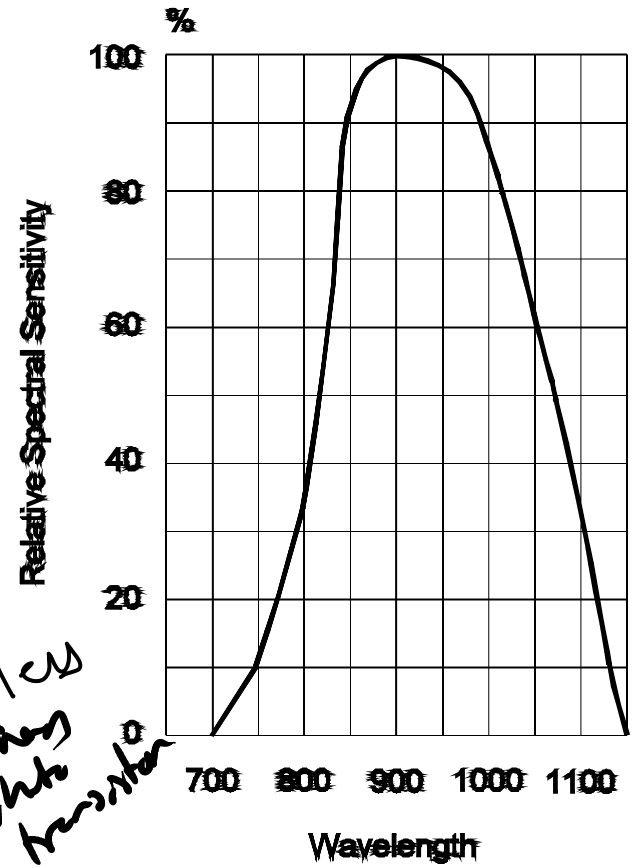
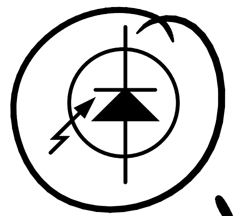


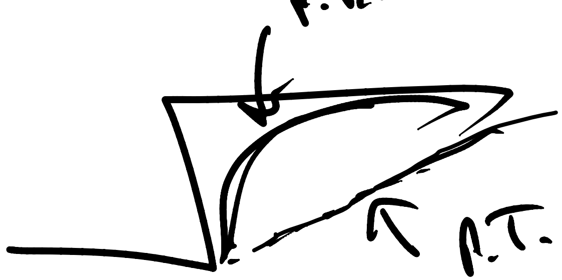
Fig.5 RELATIVE SPECTRAL SENSITIVITY VS WAVELENGTH

Basic Sensors: Light (2.2)

why use?

* large dynamic range
* no saturation





more light
↑ current leak

leak current

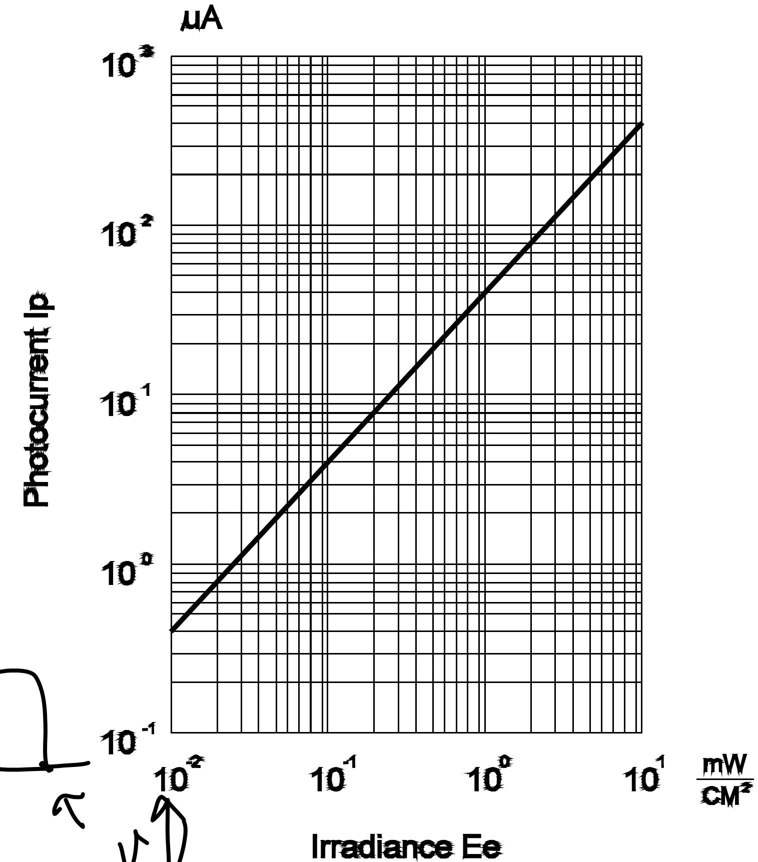


Fig.6 PHOTOCURRENT VS IRRADIANCE λ= 940 nm

Photodiode Datasheet (1.2)

LITEON

Black Plastic Photodiode

LTR-516AD/LTR-526AD/LTR-536AD/LTR-546AD

Features

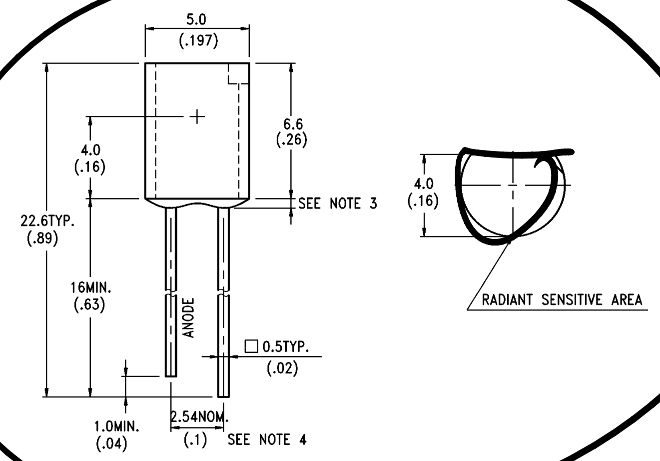
- High photo sensitivity.
- Suitable for infrared radiation.
- Low junction capacitance.
- High cut-off frequency.
- Fast switching time.

Description

The LTR-516AD/LTR-526AD/LTR-536AD/LTR-546AD are special dark plastic package that cut the visible light and suitable for the detectors of infrared applications.

Package Dimensions

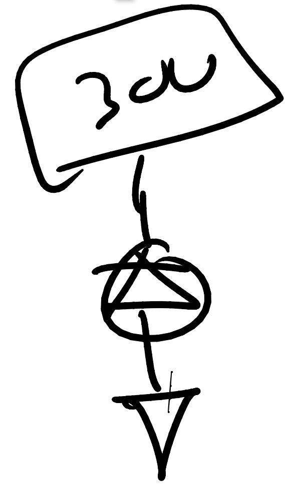
LTR-516AD



Photodiode Datasheet (2.2)

Absolute Maximum Ratings at Ta=25 ℃

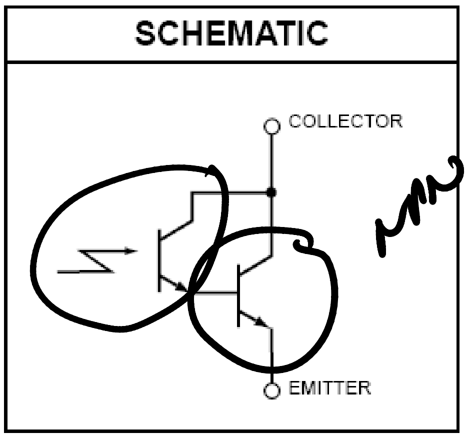
Parameter	Maximum Rating	Unit
Power Dissipation	150	mW
Reverse Break Down Voltage	30	V
Operating Temperature Range	-55 ℃ to + 100 ℃	
Storage Temperature Range	-55 ℃ to + 100 ℃	
Lead Soldering Temperature [1.6mm (.063 in.) from body]	260 ℃ for 5 Seconds	

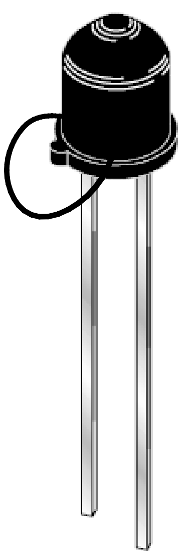


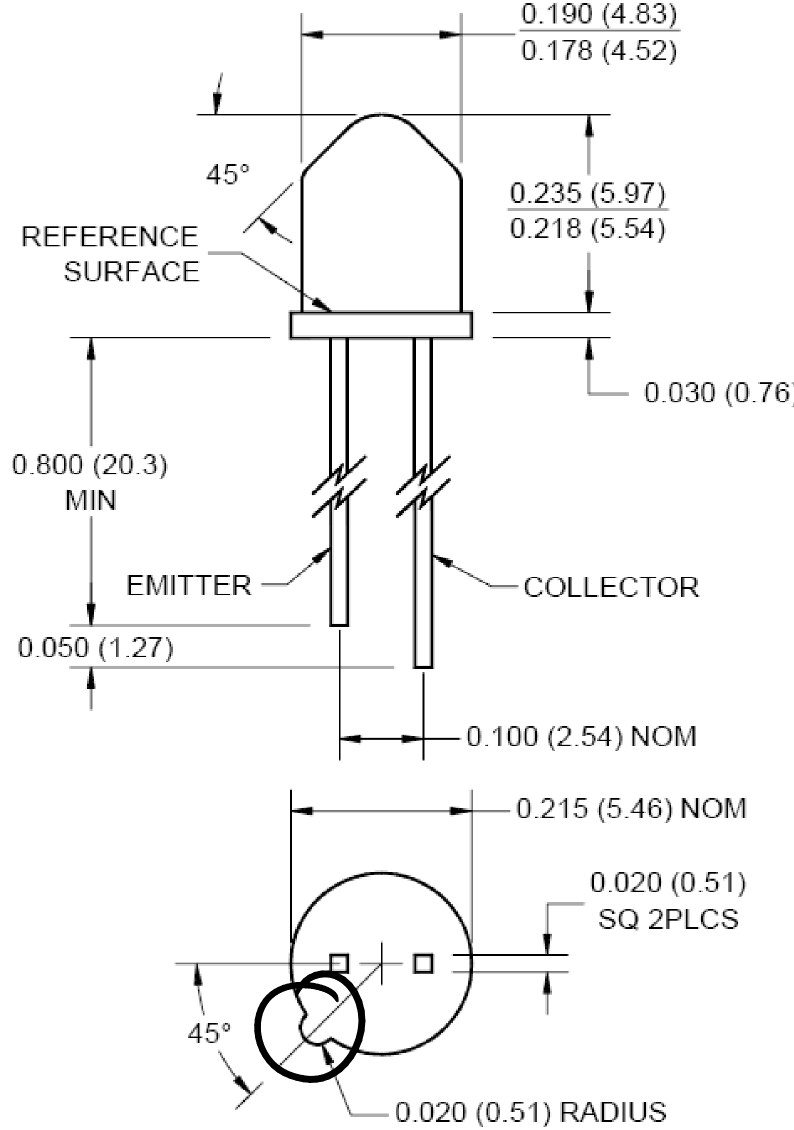
Electrical Optical Characteristics at Ta=25 ℃

Parameter	Symbol	Min.	Typ.	Max.	Unit	Test Condition
Reverse Break Down Voltage	$V_{(BR)R}$	30			V	I_R=100 μA Ee=0mW/cm^2
Reverse Dark Current	$I_{D(R)}$			30	nA	V_R=10V Ee=0mW/cm^2
Open Circuit Voltage	V_{OC}		350		mV	λ =940nm Ee=0.5mW/cm^2
Rise Time	T_r		50		nsec	V_R=10V λ =940nm R_L=1K Ω
Fall Time	T_f		50		nsec	
Light Current	I_S	1.7	2		μ A	V_R=5V λ =940nm Ee=0.1mW/cm^2
Total Capacitance	C_T		25		pF	R=3V V_F=1MHZ Ee=0mW/cm^2
Wavelength of the Max Sensitivity	λ SMAX		950		nm	

The Photo-Darlington







ABSOLUTE MAXIMUM RATINGS (T_A = 25°C unless otherwise specified)

Parameter	Symbol	Rating	Unit
Operating Temperature	T_{OPR}	-40 to +100	°C
Storage Temperature	T_{STG}	-40 to +100	°C
Soldering Temperature (Iron)(2,3,4)	T_{SOL-I}	240 for 5 sec	°C
Soldering Temperature (Flow)(2,3)	T_{SOL-F}	260 for 10 sec	°C
Collector-Emitter Voltage	V_{CE}	30	V
Emitter-Collector Voltage	V_{EC}	5	V
Power Dissipation(1)	P_D	100	mW

ELECTRICAL / OPTICAL CHARACTERISTICS (T_A =25°C)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
Peak Sensitivity Wavelength		λ_{PS}	—	880	—	nm
Reception Angle		Θ	—	±20	—	Deg.
Collector-Emitter Dark Current	V_{CE} = 10 V, Ee = 0	I_{CEO}	—	—	100	nA
Collector-Emitter Breakdown	I_C = 1 mA	BV_{CEO}	30	—	—	V
Emitter-Collector Breakdown	I_E = 100 μA	BV_{ECO}	5	—	—	V
On-State Collector Current(5)	Ee = 0.125 mW/cm^2, V_{CE} = 5 V	$I_{C(ON)}$	5.0	—	—	mA
Saturation Voltage(5)	Ee = 0.125 mW/cm^2, I_C = 2.0 mA	$V_{CE(sat)}$	—	—	1.0	V
Rise Time	V_{CC} = 5 V, R_L = 100 Ω, I_C = 0.15 mA	t_r	—	20	—	μs
Fall Time		t_f	—	50	—	μs

RT 1-2 mA

Figure 1. Light Current vs. Radiant Intensity

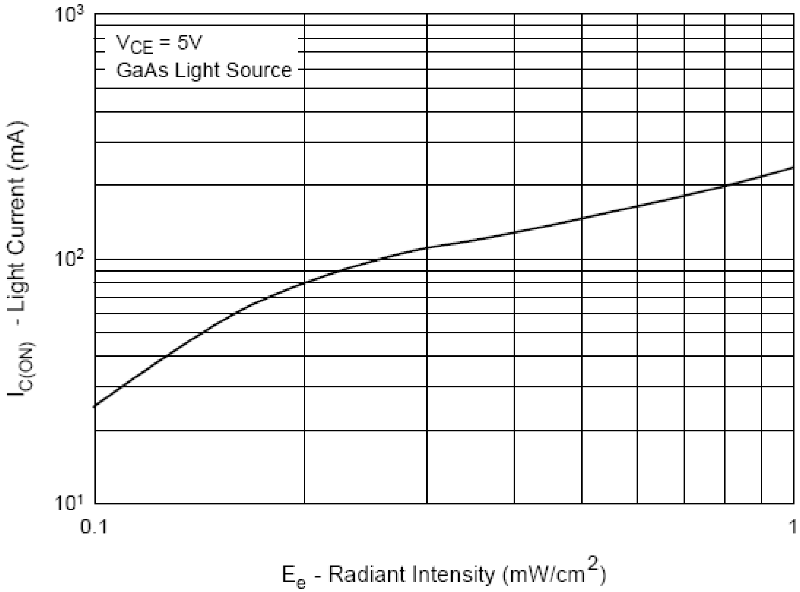
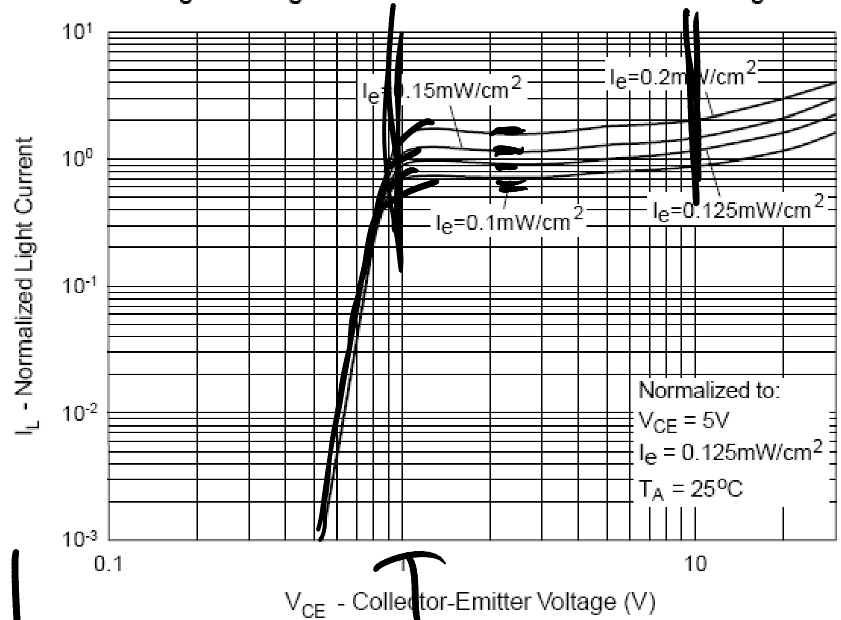


Figure 4. Light Current vs. Collector - Emitter Voltage



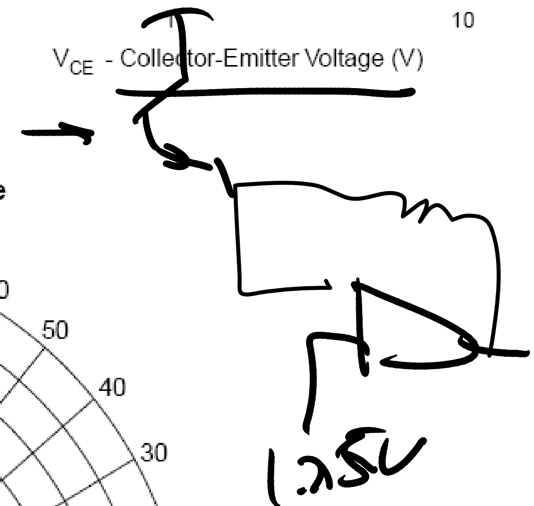


Figure 2. Angular Response Curve