Mechatronic Systems

MicroController

Decision Making

World to Signal

Actuation

The World

World
The World to Signal

Sensors or Transducers

Convert one physical phenomenon to another

Examples that you Encounter Daily
What can the Microcontroller Measure?
Basic Sensors: Light

PhotoCells

**CdS** Resistance Varies with Incident Light
More Light = Lower Resistance

Spectral Response
Approximates Human Eye

Dynamic Response

Power Rating
## CdS Photocell Specifications

**Components**
Detectors and Light Sources

**Opto-semiconductors: CdS Photoconductive Cells**
These cells have a spectral response close to the human eye.

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Package (mm)</th>
<th>Peak Sensitivity Wavelength (\lambda_p) (nm)</th>
<th>Resistance at 0 lx *2</th>
<th>Rise Time *4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\text{Min.} - \text{Max.} ) &amp; (\text{Min.} )</td>
<td>(0 \text{ to } 63 % ) 10 lx</td>
<td></td>
</tr>
<tr>
<td>P1114-04</td>
<td>TO-18</td>
<td>570</td>
<td>15 to 45</td>
<td>10</td>
</tr>
<tr>
<td>P320</td>
<td>Metal</td>
<td>520</td>
<td>35 to 100</td>
<td>20</td>
</tr>
<tr>
<td>P559</td>
<td>(\phi 5.5)</td>
<td>540</td>
<td>2.9 to 8.5</td>
<td>0.1</td>
</tr>
<tr>
<td>P930</td>
<td></td>
<td>560</td>
<td>7 to 23</td>
<td>0.5</td>
</tr>
<tr>
<td>P1465</td>
<td></td>
<td>520</td>
<td>27 to 81</td>
<td>10</td>
</tr>
</tbody>
</table>

*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 10lx.

*4: Gamma characteristics between 10lx and 100lx.

\[ \gamma_{10} = \log\left(\frac{R_{10}}{R_{100}}\right) \]

\[ \gamma_{100} = \log\left(\frac{R_{100}}{R_{10}}\right) \]

Gamma characteristics variations of 0.10.

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EE/CS118 Sensors Lecture
CdS Photocells: How do you use them?

In a voltage divider to generate a voltage

Anywhere you can use a resistor to vary a circuit’s output
Basic Sensors: Light

Photo-Transistors

NPN only

Light Replaces the base current

Spectral Response

Dynamic Response

Spectral sensitivity characteristics

Wavelength $\lambda$ (nm)

$V_{CE} = 10V$
$T_a = 25^\circ C$
Directional Characteristics

\[ I_{CE(L)} - L \]

Sensitivity/Linearity

Illuminance \( L \) (lx)

Collector photo current \( I_{CE(L)} \) (mA)

Relative sensitivity \( S(\%) \)

Directivity characteristics

\[ V_{CE} = 10V \]
\[ T_a = 25^\circ C \]
\[ T = 2856K \]
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-peeking 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 blocks the visible light and is suitable for the detectors of infrared applications.

PACKAGE DIMENSIONS

NOTES:

- All dimensions are in millimeters (inches).
- Tolerance is ±0.25mm (.010") unless otherwise noted.
- Protruded resin under flange is 1.5mm (.059") max.
- Lead spacing is measured where the leads emerge from the package.
- Specifications are subject to change without notice.
### Absolute Maximum Ratings at $T_A = 25^\circ C$

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MAXIMUM RATING</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>100</td>
<td>mW</td>
</tr>
<tr>
<td>Collector-Emitter Voltage</td>
<td>30</td>
<td>V</td>
</tr>
<tr>
<td>Emitter-Collector Voltage</td>
<td>5</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$-55^\circ C$ to $+100^\circ C$</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$-55^\circ C$ to $+100^\circ C$</td>
<td></td>
</tr>
<tr>
<td>Lead Soldering Temperature</td>
<td>260$^\circ C$ for 5 Seconds</td>
<td></td>
</tr>
</tbody>
</table>

### Electrical Characteristics at $T_A = 25^\circ C$

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>PART NO LTR—</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
<th>TEST CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-Emitter Breakdown Voltage</td>
<td>$V_{(B!!E)!CE}$</td>
<td>30</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td></td>
<td>$I_C = 1 \text{ mA}$ $E_e = 0 \text{ mW/cm}^2$</td>
</tr>
<tr>
<td>Emitter-Collector Breakdown Voltage</td>
<td>$V_{(B!!E)!EC}$</td>
<td>5</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td></td>
<td>$I_E = 100 \mu\text{A}$ $E_e = 0 \text{ mW/cm}^2$</td>
</tr>
<tr>
<td>Collector Emitter Saturation Voltage</td>
<td>$V_{CE!(SAT)}$</td>
<td>0.4</td>
<td>V</td>
<td>0.5</td>
<td></td>
<td></td>
<td>$I_C = 0.5 \text{ mA}$ $E_e = 0.5 \text{ mW/cm}^2$</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$T_r$</td>
<td>10</td>
<td>$\mu S$</td>
<td></td>
<td></td>
<td>$V_{CC} = 30 \text{ V}$ $I_C = 800 \mu\text{A}$ $R_L = 1 \text{ k}\Omega$</td>
<td></td>
</tr>
<tr>
<td>Fall Time</td>
<td>$T_f$</td>
<td>5</td>
<td>$\mu S$</td>
<td></td>
<td></td>
<td></td>
<td>$V_{CE} = 10 \text{ V}$ $E_e = 0 \text{ mW/cm}^2$</td>
</tr>
<tr>
<td>Collector Dark Current</td>
<td>$I_{CEO}$</td>
<td>100</td>
<td>nA</td>
<td></td>
<td></td>
<td></td>
<td>$V_{CE} = 5 \text{ V}$ $E_e = 1 \text{ mW/cm}^2$</td>
</tr>
<tr>
<td>On State Collector Current</td>
<td>$I_{C!(ON)}$</td>
<td>3208</td>
<td>1</td>
<td>4</td>
<td></td>
<td>mA</td>
<td>$\lambda = 940 \text{ nm}$</td>
</tr>
<tr>
<td></td>
<td>3208E</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>mA</td>
<td>$\lambda = 940 \text{ nm}$</td>
</tr>
</tbody>
</table>
Phototransistors: How Do You Use Them?

Simple Ways
Phototransistors: How Do You Use Them?

Better Way

\[ \text{5V} \]

\[ \text{R1 10k} \]
Basic Sensors: Light

Photo-Diodes

Spectral Sensitivity

Speed

Light Sensitivity

Fig. 5 RELATIVE SPECTRAL SENSITIVITY VS WAVELENGTH
Wide Dynamic Range

Fig. 6 PHOTOCURRENT VS IRRADIANCE $\lambda = 940$ nm
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.
### Absolute Maximum Ratings at Ta=25 °C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>150</td>
<td>mW</td>
</tr>
<tr>
<td>Reverse Break Down Voltage</td>
<td>30</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-55 °C to +100 °C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>-55 °C to +100 °C</td>
<td></td>
</tr>
<tr>
<td>Lead Soldering Temperature</td>
<td>260 °C for 5 Seconds</td>
<td></td>
</tr>
</tbody>
</table>

### Electrical Optical Characteristics at Ta=25 °C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse Break Down Voltage</td>
<td>V_{BR}</td>
<td>30</td>
<td>50</td>
<td></td>
<td>V</td>
<td>(V_R=10V) (=940nm) (E_e=0.5mW/cm^2)</td>
</tr>
<tr>
<td>Reverse Dark Current</td>
<td>I_D</td>
<td>30</td>
<td>50</td>
<td></td>
<td>nA</td>
<td>(V_R=10V) (\lambda=940nm) (R_L=1K\Omega)</td>
</tr>
<tr>
<td>Open Circuit Voltage</td>
<td>V_OC</td>
<td>350</td>
<td>50</td>
<td></td>
<td>mV</td>
<td>(V_R=5V) (\lambda=940nm) (E_e=0.1mW/cm^2)</td>
</tr>
<tr>
<td>Rise Time</td>
<td>T_r</td>
<td>50</td>
<td></td>
<td></td>
<td>nsec</td>
<td>(V_R=10V) (\lambda=940nm) (R_L=1K\Omega)</td>
</tr>
<tr>
<td>Fall Time</td>
<td>T_f</td>
<td>50</td>
<td></td>
<td></td>
<td>nsec</td>
<td>(V_R=5V) (\lambda=940nm) (E_e=0.1mW/cm^2)</td>
</tr>
<tr>
<td>Light Current</td>
<td>I_s</td>
<td>1.7</td>
<td>2</td>
<td></td>
<td>(\mu A)</td>
<td>(R=3V) (V_F=1MHz) (E_e=0mW/cm^2)</td>
</tr>
<tr>
<td>Total Capacitance</td>
<td>C_T</td>
<td>25</td>
<td></td>
<td></td>
<td>pF</td>
<td>(R=3V) (V_F=1MHz) (E_e=0mW/cm^2)</td>
</tr>
<tr>
<td>Wavelength of the Max Sensitivity</td>
<td>(\lambda_{SMAX})</td>
<td>950</td>
<td></td>
<td></td>
<td>nm</td>
<td>(R=3V) (V_F=1MHz) (E_e=0mW/cm^2)</td>
</tr>
</tbody>
</table>
Photodiodes: how Do You Use Them?
Basic Sensors: Magnetic Field

Simplest: a Reed Switch
Basic Sensors: Magnetic Field

Hall Sensors

Semiconductors

Switches

Analog

![Diagram of a Hall Effect sensor with input signal, sensor, and output signal.](image-url)
Uni-Polar

BiPolar

Linear
Linear Sensor
Measuring Rotation

Digital
Using Bias Magnet
Basic Sensors: Temperature

Thermistors

Temperature Sensitive Resistor

Large $\Delta R$ for $\Delta T$

Non-Linear

But well understood
Basic Sensors: Temperature

Platinum Restive Temperature Devices

RTDs

Wide Temperature Range

Extremely Linear

Very Stable

Not Very Sensitive
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.
### Limited Range of Resistances

<table>
<thead>
<tr>
<th>Resistance at 0 Deg. C. ohms</th>
<th>L (mm)</th>
<th>W (mm)</th>
<th>H (mm)</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5.0 +/- 0.2</td>
<td>1.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 1</td>
</tr>
<tr>
<td>100</td>
<td>5.0 +/- 0.2</td>
<td>1.5 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 2</td>
</tr>
<tr>
<td>100</td>
<td>2.3 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 3</td>
</tr>
<tr>
<td>100</td>
<td>5.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 4</td>
</tr>
<tr>
<td>100</td>
<td>10.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 5</td>
</tr>
<tr>
<td>100</td>
<td>5.0 +/- 0.2</td>
<td>4.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P01 ln 6</td>
</tr>
<tr>
<td>100</td>
<td>1.6 +/- 0.2</td>
<td>1.25 +/- 0.1</td>
<td>1.00 +/- 0.2</td>
<td>P01 ll M7</td>
</tr>
<tr>
<td>500</td>
<td>5.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P05 ln 1</td>
</tr>
<tr>
<td>500</td>
<td>10.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P05 ln 2</td>
</tr>
<tr>
<td>500</td>
<td>5.0 +/- 0.2</td>
<td>4.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P05 ln 3</td>
</tr>
<tr>
<td>1000</td>
<td>4.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P10 ln 1</td>
</tr>
<tr>
<td>1000</td>
<td>10.0 +/- 0.2</td>
<td>2.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P10 ln 2</td>
</tr>
<tr>
<td>1000</td>
<td>5.0 +/- 0.2</td>
<td>4.0 +/- 0.2</td>
<td>1.3 +/- 0.2</td>
<td>P10 ln 3</td>
</tr>
<tr>
<td>2000</td>
<td>1.6 +/- 0.2</td>
<td>1.25 +/- 0.1</td>
<td>1.00 +/- 0.2</td>
<td>P20 ln 4</td>
</tr>
</tbody>
</table>

**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
- **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
- **0A** = 1/2 DIN B (DIN A) at 0°C

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

\[ \Delta R \text{ proportional to } R \text{ at } 0°C \]
Measuring Position

Translate Movement to ??? To Voltage

What are examples of ???
Optical Sensors for Position

Reflective

**PACKAGE DIMENSIONS**

- 0.40 (10.67)
- 0.226 (5.74)
- 0.703 (17.86)
- 0.373 (9.47)

**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 0.200“ in diameter.

**FEATURES**

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

Transmissive

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

Combine the Transmissive Optical Sensor
With a rotating Mask

48 segments
Encoder: How it works

Quadrature
Encoders: Where Do You Find Them?

Printers

Disk Drives