Sensor Report

Autonomous Miniature Forklift

Presented to

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by

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Introduction

Autonomous mobile vehicles are becoming increasingly common in the world we live around us. Autonomous vehicles have been designed and implemented to perform a wide variety of tasks, from delivering medical sample in a hospital to sweeping and clearing unexploded ordnance from a mine-field. One of the most practical and popular application for autonomous vehicles has been in the area of material handling. The use of autonomous material handling vehicles is now common in the high volume production facilities of many industries.

I chose to build an autonomous miniature forklift to increase my awareness and technical knowledge of the rapidly expanding industry of producing and using automated vehicles for material handling. The basic objectives of the project are to build a mini-forklift that could follow a line in a mini-factory floor and load and unload cargo at designated locations. The forklift would also be capable of obstacle avoidance while maneuvering the course in the mini-factory.

In order to accomplish the task of following a line in a model factory, appropriate sensors needed to be chosen and evaluated. Various types of sensors available for finding a painted line on a factory floor include photocell light sensors and infrared reflectance sensors. The photocell light sensor is a resistor that changes resistance when exposed to varying amounts of light. The infrared reflectance sensor is a phototransistor that detects the wavelengths emitted by an infrared LED it is coupled with in a small package. I performed a large variety of experiments with both types of sensors, and the results and conclusions of that work will be presented in this paper.

Background

Initially, I was planning on using Cadmium Sulfide photocells (CdS) as the sensors used to accomplish the task of line following. Class lectures and lab TA recommended the CdS cells because they had been used successfully in the past for line following robots, and were readily available and inexpensive. After building the voltage divider circuits used with the CdS cell, I was disappointed by the huge amount of variance between individual units. I had differences in resistance of greater than 10 orders of magnitude between some of the identically constructed CdS sensors. Those differences were reduced by using different resistors for the voltage dividers, but I was still unsatisfied with the performance to the CdS sensors.

After some additional research into available photo detectors, I decided to try some models of infrared reflectance sensors. These used a matched pair of an infrared emitting LED and detecting phototransistor. The come packaged together in a small, neat package. I found the photo reflectance sensors to perform far superior to the traditional CdS cells. The results are explained in the body of this paper.

Experimental Apparatus and Hardware Configuration

The experiments were performed using the TJPro board, in similar conditions to the operating environment the sensors will be used in. The apparatus for testing the sensors was set up on a table in a lab with fluorescent lights and blind covered windows. In order to control the distance the sensor was above the ground, it was attached to a straight edge with indexed increments, and placed in a vice. The sensor was aimed at the tabletop, and raised from the surface in 0.10 inch increments. At each increment, brown, white, and black colored paper was placed under the sensor, and the value was recorded. This process was repeated three times for each sensor, in order to ensure the precision of the data. The distance the sensor was test over ranged from 0 to 1.5 inches above the table surface.

A 330 Ohm resistor was wired in series with the emitter side of the sensor to regulate the current through the LED. A 47 Kohm voltage divider was constructed for used with the detector side of the sensor. A 2.2 Kohm voltage divider was also tried, but produce a very reduce range of output values, so it was not used for further testing.

The CdS cell used was obtained from the IMDL stock room and was constructed using a 47 Kohm voltage divider. The photo reflectance sensors were order from Mouser Electronics. Two different models were test, namely the QRB1114 and the QRD1114. These sensors differed in the design of their package, and in the slightly in the current handling capacity of the transistor. They are available from Mouser for $1.30 and $1.13 respectively. Detailed information about them can be viewed in the appendix.

Experimental Design

Test were performed in order to compare and evaluate my best performing CdS cell, and the two models of photo reflectance sensors. The each unit of the different models was similarly tested over the 1.5 inch range (at 0.1 inch increments) over white, black, and brown surfaces. These experiments allowed the outputs of the different models of sensors to be compared over the variable colors and distances. The testing of multiple units also allowed the different units of the same model to be compared.

Results

The complete data obtained by the experiments is include for reference in the appendix. The results are plotted and compared below, because the graphical representation of the data is much easier to interpret.

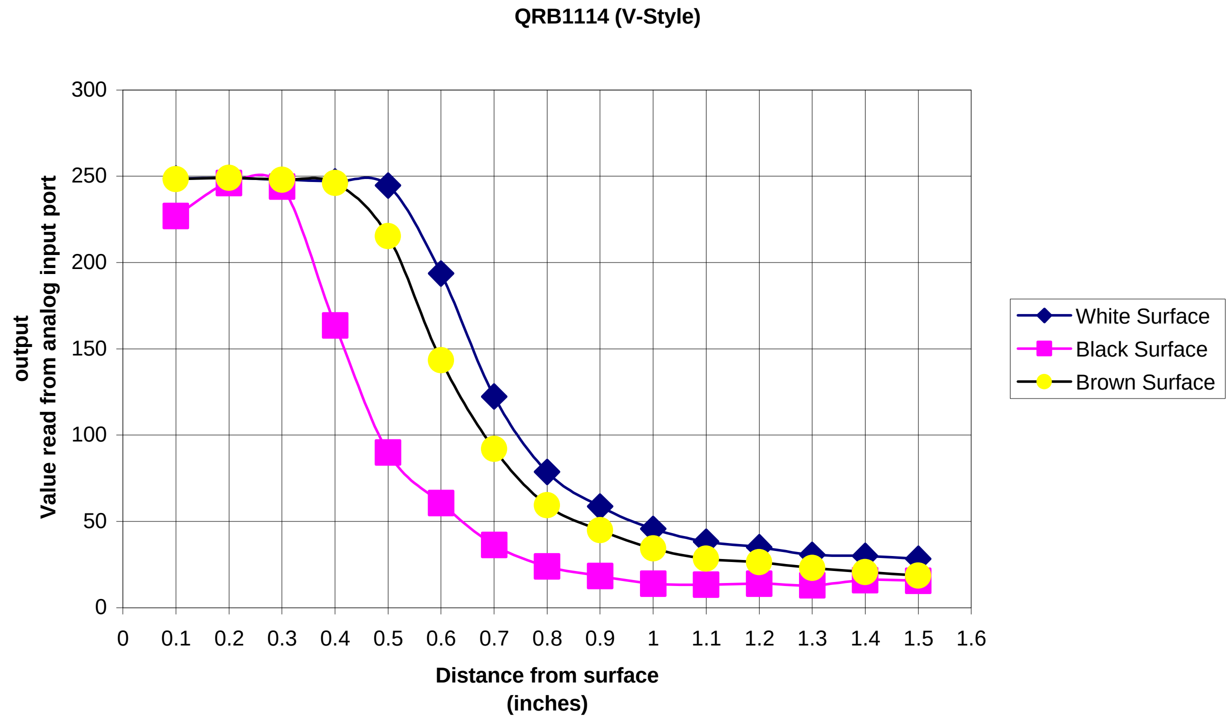


Figure 1: This graph compares the output of the QRB1114 sensor over white, black and brown surfaces.

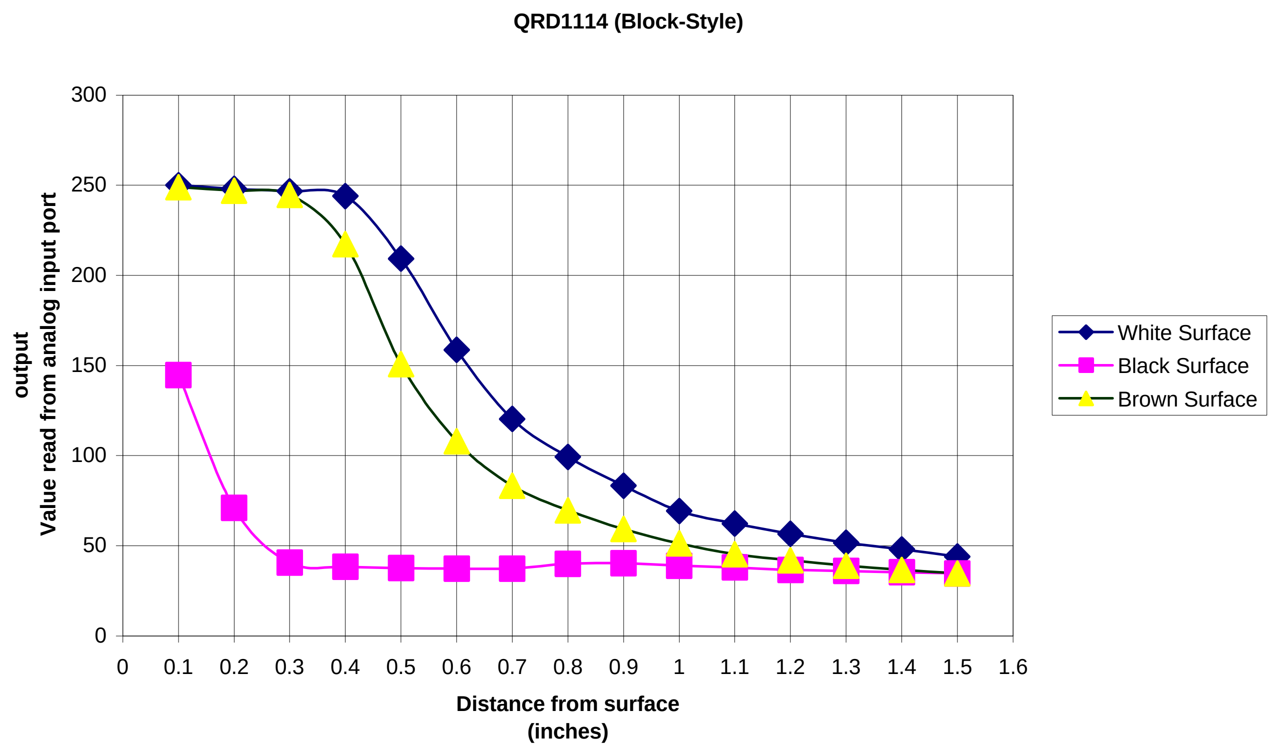


Figure 2: This graph compares the output of the QRD1114 sensor over white, black and brown surfaces.

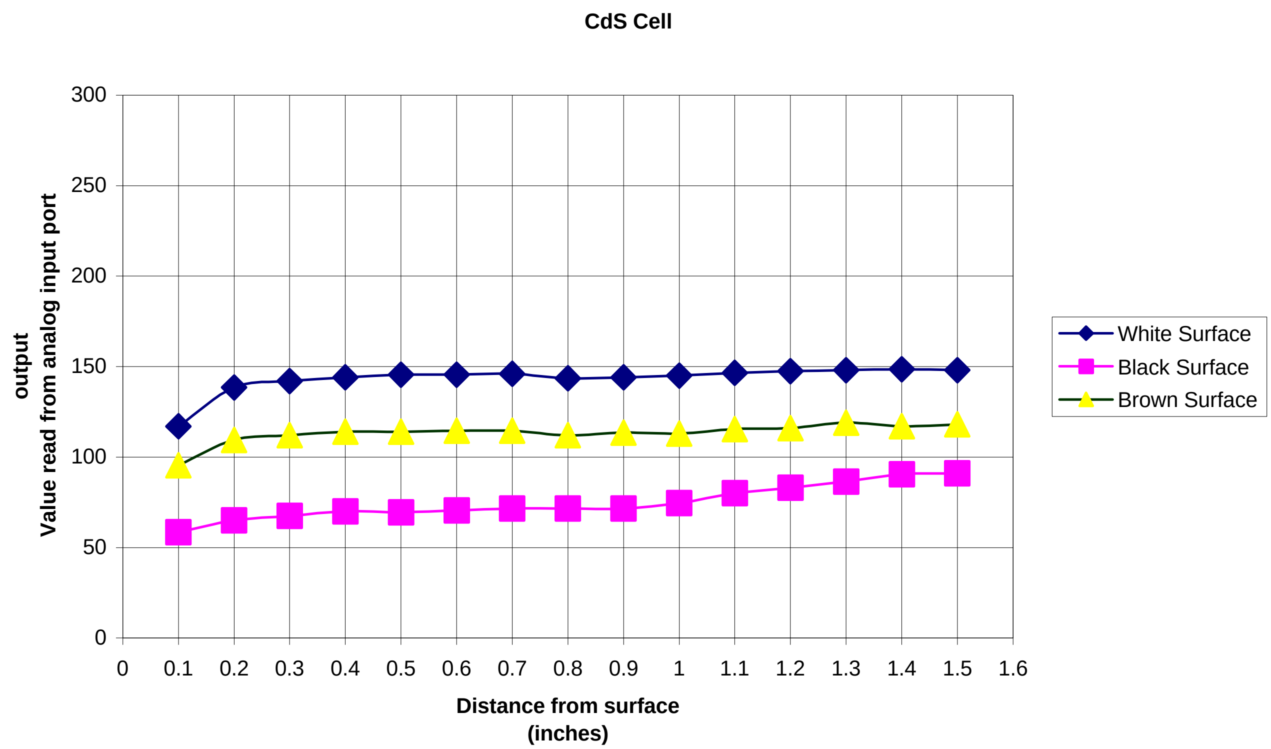


Figure 3: This graph compares the output of the CdS cell sensor over white, black and brown surfaces.

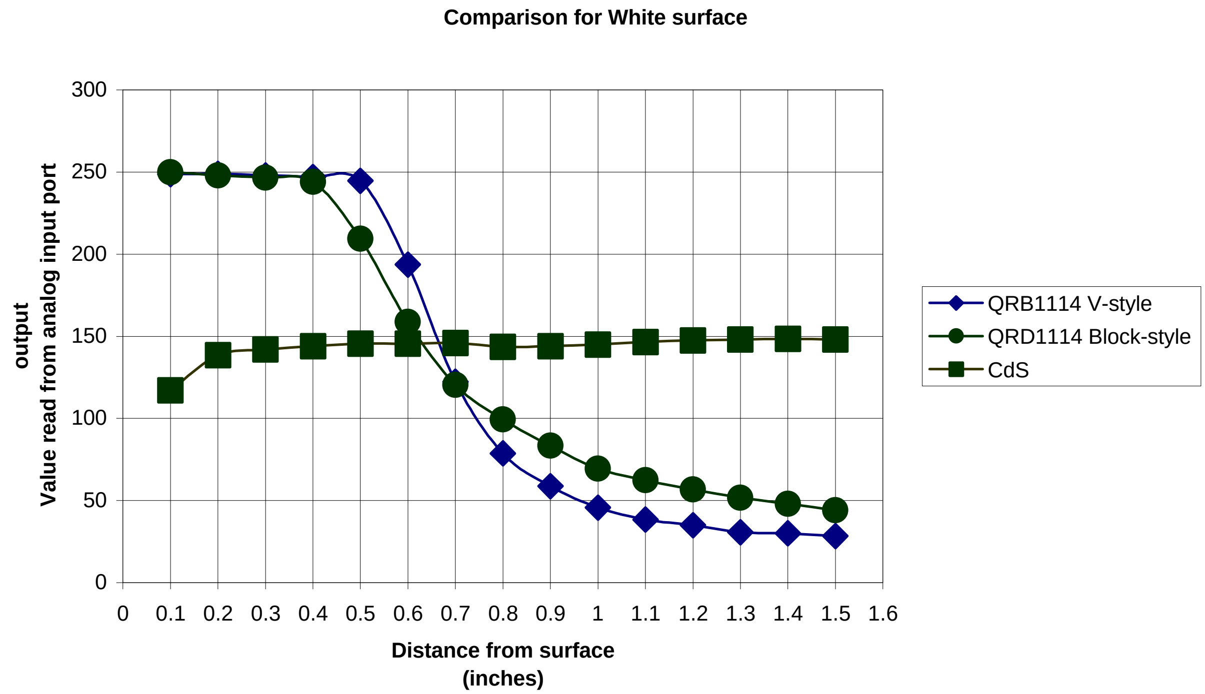


Figure 4: This graph compares the output of the CdS cell, QRB1114, QRD1114 sensors over a white background.

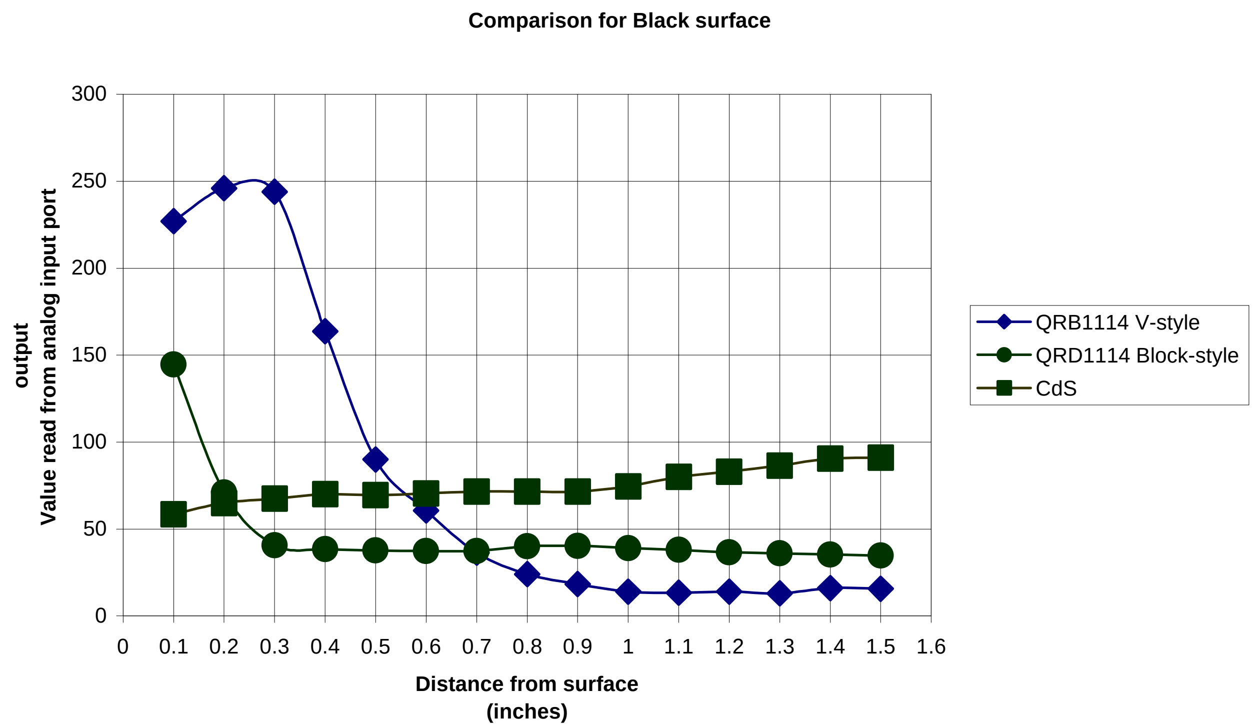


Figure 5: This graph compares the output of the CdS cell, QRB1114, QRD1114 sensors over a black background.

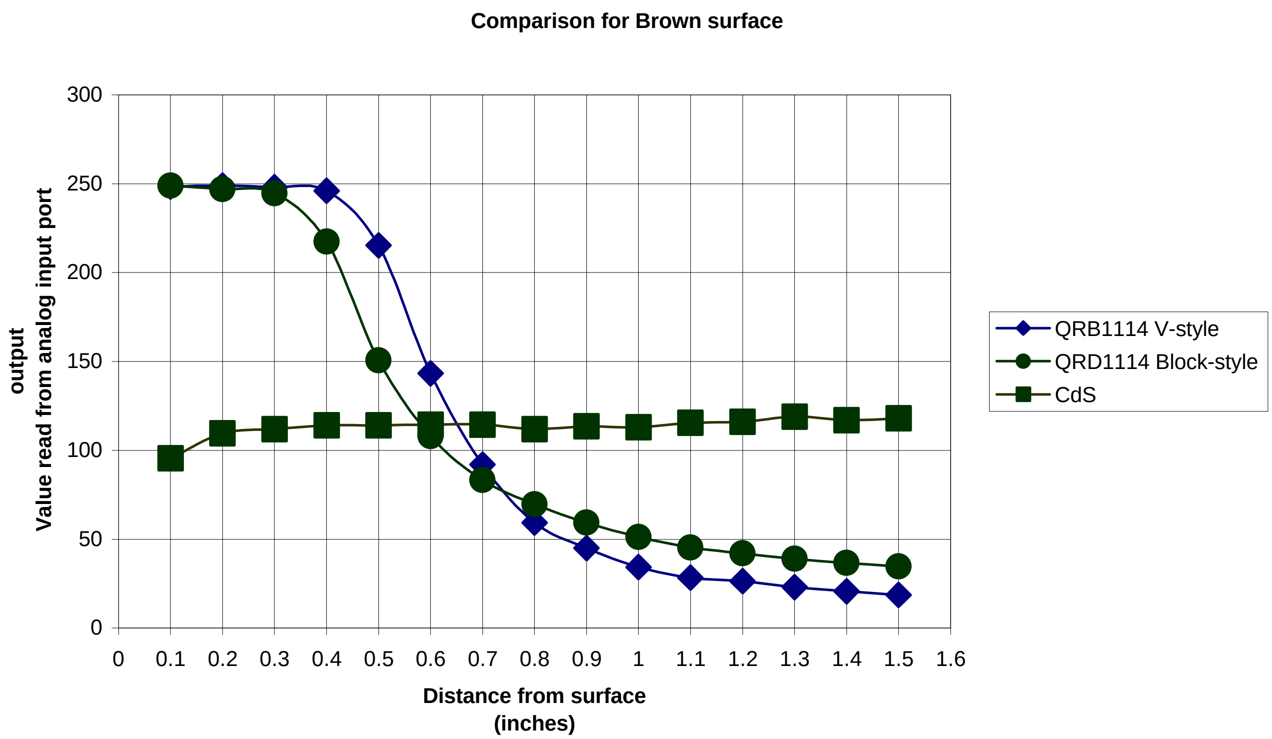


Figure 6: This graph compares the output of the CdS cell, QRB1114, QRD1114 sensors over a brown background.

Conclusion

The plots of the results make it apparent that the photo reflectance sensors outperform the traditional CdS cell for this range and application. At the 0.5 inch range, where the sensor will be mounted, the QRB1114 outputs a value difference of nearly 160 on the analog input port over white vs. black. Similar data for the CdS show that it only has a range of approx. 70, exhibiting only half the range of the photo reflectance sensor.

Between the photo reflectance sensors, the QRB1114 has slightly more sensitivity over black, while the QRD1114 showed the greatest output distance of white vs. black surfaces. The different units of the same models also exhibited minimal discrepancy in their performance.

The most outstanding feature of the completed robot are the silicon photo transistors IR emitter detector pairs (photo reflectance sensors) used for line following. These sensors performed exceptionally well under vastly varied conditions, and saved me much trouble encountered by others using CdS cell for similar tasks. I would recommend these sensors to anyone who is interested in detecting dark and light colors. These sensors are available from Mouser Electronics with part numbers 512-QRB1114 and 512-QRD1114 for slightly more than a dollar each. The 512-QRD1114 are slightly cheaper, smaller, and seemed to perform slightly better than the other model.

Appendix

Detailed Sensor Info for 512-QRB1114 and 512-QRD1114.

MOUSER ELECTRONICS Catalog No. 609 February 2002 to April 2002 sales@mouser.com www.mouser.com (800) 346-6873

FAIRCHILD SEMICONDUCTOR Optoelectronic Products

INFRARED EMITTING DIODES AND PHOTO DETECTORS

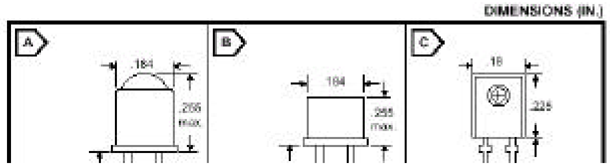
Infrared Emitting Diodes

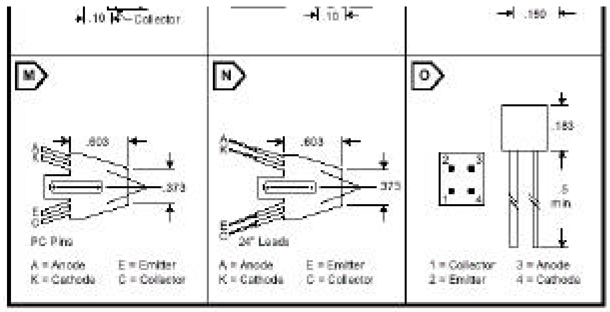
For quantities greater than listed, call for quote.

MOUSER STOCK NO.		Fig.	Min. Power Output	Max. Fwd Volt	Peak Emission Wave-Length	Beam Angle +/-	Price Each		
Mfr.	Industry No.						1	100	500
512-1N6264		A	6mW	1.7V	940	10	2.00	1.60	1.47
512-1N6265		B	6mW	1.7V	940	40	2.00	1.60	1.47

512-QSD122	E	1.0	30	10 / 100	.35	.28	.26
512-QSD123	E	4.0	30	10 / 100	.38	.30	.28
512-QSD124	E	6.0	30	10 / 100	.40	.32	.29
512-QSD423	F	1.2	30	10 / 100	.60	.48	.44
512-QSD722	J	0.6	30	10 / 100	.35	.28	.26
512-QSD723	J	2.5	30	10 / 100	.40	.32	.29
512-QSD724	J	3.5	30	10 / 100	.43	.34	.31
512-QSE113	G	0.25	30	10 / 100	.25	.20	.18
512-QSE114	G	1.0	30	10 / 100	.28	.22	.20
Photo Darlington							
512-BPW38	H	3.0	25	12 / 100	2.13	1.70	1.56
512-L14F1	H	3.0	25	12 / 100	2.08	1.66	1.53
512-L14F2	H	1.0	25	12 / 100	1.93	1.54	1.42
512-L14R1	C	5.0	30	25 / 100	.38	.30	.28

DIMENSIONS (IN.)





OPTOLOGIC™ PHOTOSENSORS

For quantities greater than listed, call for quote.

MOUSER STOCK NO.		Fig.	Positive Threshold mw/cm²	Function	VCC (V)	Price Each		
Mfr.	Industry No.					1	100	500
512-L14LOB		K	.250	Buff O/C	4.5-16.0	.73	.58	.53
512-L14LOI		K	.250	Inv O/C	4.5-16.0	.73	.58	.53
512-QSE156		L	.250	Buff T/P	4.5-16.0	.78	.62	.57
512-QSE157		L	.250	Inv T/P	4.5-16.0	.78	.62	.57
512-QSE158		L	.250	Buff O/C	4.5-16.0	.78	.62	.57
512-QSE159		L	.250	Inv O/C	4.5-16.0	.78	.62	.57

REFLECTIVE PHOTOSENSORS Photo Transistor Output

MOUSER STOCK NO.		Fig.	On-State Collector Current	IF/VCE	BV CEO (V)	Price Each		
Mfr.	Industry No.					1	100	500
512-QRB1114		M	.60mA	40mA/5V	30	1.30	1.04	.96
512-QRB1134		N	.60mA	40mA/5V	30	2.33	1.86	1.71
512-QRD1114		O	1.0mA	20mA/5V	30	1.13	.90	.83

MATCHED EMITTER / DETECTOR PAIRS

• Emitter color: black

For quantities greater than listed, call for quote.

MOUSER STOCK NO.		Fig.	IC (On) (mA) min.	IF / VCE	Detector Stripe Color	BV CEO (V)	Price Each		
Mfr.	Industry No.						1	100	500
Photo Transistor / LED Pairs									
512-H23A1		C	1.5	30mA / 5V	Red	30	.70	.56	.52
Photo Darlington / LED Pairs									
512-H23B1		C	7.5	10mA / 1.5V	Yellow	30	.85	.68	.63

Optologic™/ LED Pairs

• Emitter: Figure C • Detector: Figure K • Operating supply voltage: 4.0V to 16.0V

MOUSER STOCK NO.		Fig.	Hysteresis Ratio (Typ) IF(+)/IF(-)	Positive Threshold		Price Each		
Mfr.	Industry No.			Turn On	Turn Off	1	100	500
512-H23LOB		C/K	1.2	10mA	7.5mA	1.18	.94	.86
512-H23LOI		C/K	1.2	10mA	7.5mA	1.18	.94	.86

98

177% 1 of 1 7.75 x 10.85 in