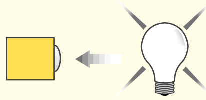
Understanding Sensing Terms

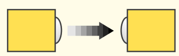
Data Reference Tables

Other Banner Products

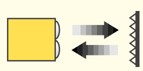
International Distributor List

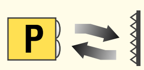


AMBIENT LIGHT RECEIVERS: Ambient light receivers, such as MULTI-BEAM model SBAR1, are operated by sunlight, room light, or laser light sources. These sensors are also used to sense the large amounts of infrared light (heat energy) emitted by hot or molten glass, metal, or plastic during processing of these materials.

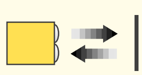


OPPOSED (A.K.A. "THROUGH-BEAM") SENSING MODE: The opposed mode requires a separate emitter and receiver that are positioned opposite each other so that the light from the emitter shines directly on the receiver. An object is sensed when it interrupts the light beam. The opposed mode is the most efficient use of photoelectric sensing energy, and offers the highest level of excess gain for reliable sensing through dirt, fog, or other challenging environments.

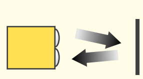




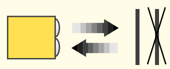
RETROREFLECTIVE (A.K.A. "RETRO") SENSING MODE: Retroreflective mode sensors have both the emitter and the receiver in the same housing. A light beam is established between the sensor and a special retroreflective target (see page 722). An object is sensed when it interrupts the light beam. Retro is the most popular sensing mode for conveyor control and similar applications where there is an advantage to have a sensor on only one side of the sensing process. Polarized retroreflective sensors are used when the object to be detected is highly reflective. Special laser retro sensors, such as Q45LL (page 382), offer very long range and accurate sensing repeatability.



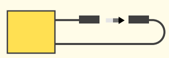
DIFFUSE (A.K.A. "PROXIMITY") SENSING MODE: Diffuse mode sensors contain both the emitter and the receiver in the same housing. An object is detected when the receiver captures the small percentage of emitted light that is reflected back to the sensor from the surface of the object itself. Minimal lensing is used so as to project the emitted light in a broad (diffused) pattern and give the receiver a wide field of view. Special models called divergent mode sensors use no lenses at all for extremely forgiving alignment to objects that are difficult for reflective sensors to sense, such as clear materials and very small parts.

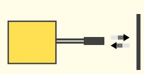


CONVERGENT BEAM SENSING MODE: The convergent mode is similar to the diffuse sensing mode because an object is sensed when the receiver sees light reflected back to the sensor by the object itself. Unlike diffuse mode sensors, however, convergent sensors use additional optics to produce a small and well-defined sensing area, focused at a fixed point ahead of the sensor lens. Because convergent sensors make much more efficient use of sensing light energy, they can sense relatively non-reflective materials and objects with small reflective surfaces. They are, however, much less forgiving to sensing distance, as compared to diffuse mode sensors.

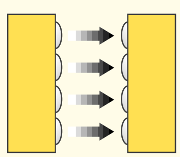


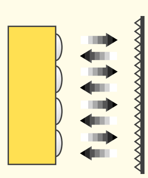
FIXED-FIELD AND ADJUSTABLE FIELD SENSING MODES: Fixed-field sensors use two receivers and a comparator circuit to cancel sensing response whenever the intensity of the reflected light reaching the long-range receiver exceeds the intensity of the reflected light reaching the close-range receiver. As a result, any object lying beyond the sensor's fixed "cutoff point" can be reliably ignored. Adjustable field sensors use an array of multiple receiver elements, which allows the sensor circuitry to move the locations of the cutoff point with a simple adjustment.



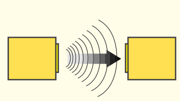


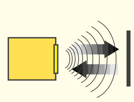
FIBER OPTIC SENSING MODES: Transparent fibers of glass or plastic may be used for conducting and guiding photoelectric sensing light energy. Individual fibers are usually used in pairs for opposed mode sensing. Bifurcated fibers combine the emitted and received light in the same assembly, and are usually used for diffuse mode sensing. Bifurcated fiber optics are sometimes fitted with an optional lens for retroreflective mode sensing. Fiber optics comprise the smallest photoelectric sensors and can fit into extremely tight spaces. Most glass fiber optics are able to withstand sensing environments where there are corrosive materials and/or where the temperature is too high for sensor electronics. Most sensor families include models for use with fiber optics.



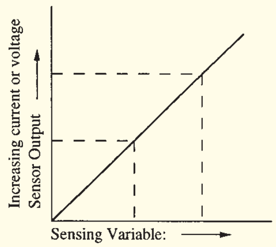


LIGHT SCREENS (A.K.A. LIGHT CURTAINS): A light screen is an array of photoelectric beams configured to sense objects passing anywhere through an area (i. e. - through a sensing plane). Some light screens, such as MINI-ARRAY or BEAM-ARRAY™ models work together with a microprocessor-based controller to measure and/or profile one dimension of an object that passes through the sensing plane (See the Banner Measurement and Inspection Sensor Catalog). Other light screens, such as LS Series sensors (page 526), are designed simply for sensing the presence of a part in the sensing plane, and are usually used for parts counting or die ejection verification. Safety light screens, such as the MINI-SCREEN®, include the necessary self-checking redundant circuitry necessary to allow their use in personnel safety applications. See the Banner Machine Safety Products Catalog and the "Important Safety Warning" inside the front cover of this catalog.

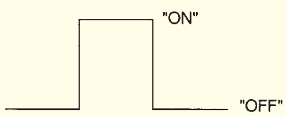




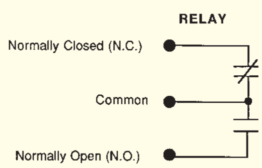
ULTRASONIC SENSING MODES: Ultrasound may be used for opposed mode or reflective proximity mode detection of clear materials and other objects that are difficult to detect with photoelectric sensors. Ultrasonic proximity mode sensors measure the time delay between the emitted sound and the returned echo, and produce an accurate measurement of sensing distance. Ultrasonic analog proximity sensors produce an output that has a highly linear relationship to sensing distance. Ultrasonic proximity sensors with switched outputs, such a OMNI-BEAM™ and Q45U models, offer a "high/low level" mode that can directly control fill level of liquids or solids. (See the Banner Measurement and Inspection Sensor Catalog)



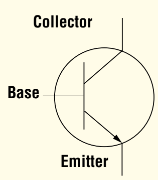
ANALOG RESPONSE: Most sensors offer a switched (discrete) output. Sensors with an analog output produce a variable voltage or current that is proportional to some sensing parameter. The output of an analog photoelectric sensor is proportional to the strength of the received light signal (see Analog OMNI-BEAM™ sensors, page 444). The output of an analog ultrasonic proximity mode sensor is proportional to the distance from the sensor to the object that is returning the sound echo. (See the Banner Measurement and Inspection Sensor Catalog)



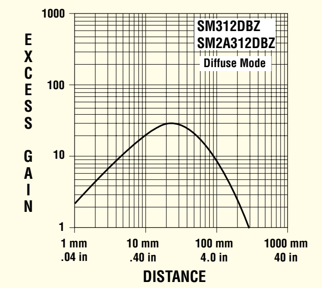
SWITCHED (A.K.A. DISCRETE OR BINARY) OUTPUT: Most sensors are used for presence sensing and offer a relay as an output switching device. The relay switch is always in either one of two states: open or closed ("ON" or "OFF").



ELECTROMECHANICAL ("E/M") RELAYS offer one or more "hard" contacts (metal-to-metal) and are switched to the opened or closed position by applying voltage to an electromagnetic coil. E/m relays can switch the highest power levels. They are limited by slow switching speed and a finite mechanical life.

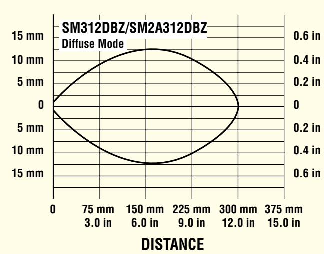


SOLID-STATE RELAYS use switching elements such as transistors for dc loads and SCRs or FETs for ac loads. Solid-state relays offer fast switching speed and infinite life. They are limited by their power ratings, and are protected in most sensors against damage from overload by additional circuitry.



EXCESS GAIN: Excess gain is a photoelectric sensor specification. It is a measurement of the amount of light falling on the receiver over and above the minimum amount of light required to just operate the sensor's amplifier. Excess gain is plotted versus sensing distance. Excess gain values are used to predict the reliability of a photoelectric sensor operating in a known sensing environment (see, below).

Excess Gain Guidelines	
Operating Environment	**Excess Gain Required**
CLEAN AIR: No dirt buildup on lenses or reflectors	1.5
SLIGHTLY DIRTY: Slight buildup of lint, paper, dust, moisture, or film on lenses or reflectors; lenses cleaned regularly	5
MODERATELY DIRTY: Obvious contamination of lenses and reflector, but not obscured; lenses cleaned occasionally or when necessary	10
VERY DIRTY: Heavy contamination of lenses; fog, mist or dust; minimal cleaning of lenses	50 or more



BEAM PATTERN: Beam patterns are two-dimensional plots of sensor response versus sensing distance. They can be helpful in predicting sensor performance. A beam pattern for an opposed mode sensor pair represents the boundary within which the receiver will effectively "see" the emitted light beam, assuming no angular misalignment between the emitter and receiver. Retroreflective beam patterns are plotted using a model BRT-3 retroreflective target. Diffuse and convergent mode beam patterns represent the boundary within which the edge of 200 x 250 mm (8 x 10 in) Kodak 90% reflectance white test card is detected as it moves into the sensing area. A beam pattern is affected by many sensing variables, and should be considered as a guideline and not as an exact specification.

ENVIRONMENTAL RATING: Banner sensors and modules are rated for their suitability for use in various sensing environments using two rating systems: National Electrical Manufacturers Association (NEMA) and The International Electrotechnical Commission (IEC).

NEMA Standards Publication No. 250 guidelines are outlined:

NEMA 1	Indoor Use	Protects against accidental contact by personnel & falling dirt
NEMA 2	Indoor Use	Protects against falling dirt, liquid & light splash
NEMA 3	Outdoor Use	Protects against rain, sleet, snow, dirt & dust
NEMA 3S	Outdoor Use	Protects against rain, sleet, snow, dirt, dust & ice buildup
NEMA 4	In- or Outdoor	Protects against dirt, dust, hosedown (and heavy splash)
NEMA 4X	In- or Outdoor	Protects against dirt, dust, hosedown & corrosion
NEMA 6	In- or Outdoor	Protects against dirt, dust, hosedown & occasional submersion
NEMA 6P	In- or Outdoor	Protects against dirt, dust, hosedown & prolonged submersion
NEMA 7	Indoor Use	For use in areas of explosive gases or vapors or combustible dust
NEMA 9	Indoor Use	For use in areas of atmospheres containing combustible dust
NEMA 12	Indoor Use	Protects against dirt, dust, light splash & oil or coolant seepage
NEMA 13	Indoor Use	Protects against dirt, dust, light splash & oil or coolant spray

The rating system established by IEC Publications 144 and 529 define the following "IP" ratings:

1ST CHARACTERISTIC: Protection against contact and penetration of solid bodies

Numeral	Short Description
0	Non-protected
1	Protected against solid objects greater than 50 mm
2	Protected against solid objects greater than 12 mm
3	Protected against solid objects greater than 2.5 mm
4	Protected against solid objects greater than 1.0 mm
5	Dust protected
6	Dust-tight

2ND CHARACTERISTIC: Protection against the penetration of liquids

Numeral	Short Description
0	Non-protected
1	Protected against dripping water
2	Protected against dripping water when tilted up to 15°
3	Protected against spraying water
4	Protected against splashing water
5	Protected against water jets
6	Protected against heavy seas
7	Protected against the effects of immersion
8	Protected against submersion

INTRINSICALLY-SAFE (A.K.A. "I.S.") SENSORS: Intrinsic safety is a design technique applied to electrical equipment, including sensors, for use in hazardous (explosive) locations. The technique involves limiting electrical and thermal energy to a level below that required to ignite a specific hazardous atmosphere. I.S. sensors are used with intrinsic safety barriers, which are protective components designed to limit the voltage and current within the hazardous atmosphere. See the SMI912 Series, page 356 and the SMI30 Series, page 290.

NAMUR SENSORS: NAMUR photoelectric sensors are 2-wire devices that change their internal resistance relative to the intensity of the received light. They are designed for use with certified switching amplifiers with intrinsically-safe circuits, which convert this change to a binary output signal. NAMUR sensors are most commonly used in hazardous (explosive) sensing environments. See the Q45AD9 Series, page 414 and the MIAD9 Series, page 146.

TABLE 1. Units for Photoelectric Specifications

Unit	Symbol	Physical Quantity
ac volts	V ac	electrical potential – alternating current
ampere	A	electrical current
dc volts	V dc	electrical potential – direct current
degrees Celsius	°C	temperature (see Table 8)
degrees Fahrenheit	°F	temperature (see Table 8)
Hertz	Hz	frequency
lumen*	lm	light energy
lux	lx	illumination (lm/m^2)
meter	m	length
microamp	µA	electrical current (10^{-6} A)
microsecond	µs	time (10^{-6} s)
milliamp	mA	electrical current (10^{-3} A)
millimeter	mm	length (10^{-3} m)
millisecond	ms	time (10^{-3} s)
nanometer	nm	length (light wavelength)
ohm	Ω	electrical resistance
second	s	time
volt	V	electrical potential
volt-amp	VA	power
watt	W	power

*1 lumen = 0.001496 watt of monochromatic light at a wavelength of 546 nm

TABLE 2. Unit Prefixes

Decimal Equivalent	Prefix	Symbol	Exponential Expression
1 000 000 000 000	tera	T	10^{12}
1 000 000 000	giga	G	10^{9}
1 000 000	mega	M	10^{6}
1 000	kilo	k	10^{3}
100	hecto	h	10^{2}
10	deka	da	10
0.1	deci	d	10^{-1}
0.01	centi	c	10^{-2}
0.001	milli	m	10^{-3}
0.000 001	micro	µ	10^{-6}
0.000 000 001	nano	n	10^{-9}
0.000 000 000 001	pico	p	10^{-12}

TABLE 3. English-Metric Conversion

Inch Fraction	Inch Decimal	Millimeter	Inch Fraction	Inch Decimal	Millimeter	Inch Fraction	Inch Decimal	Millimeter
---	.0039	0.1	9/32	.2812	7.144	21/32	.6562	16.669
---	.0079	0.2	19/64	.2969	7.541	---	.6693	17
---	.0118	0.3	5/16	.3125	7.938	43/64	.6719	17.066
1/64	.0156	0.397	---	.3150	8	11/16	.6875	17.462
---	.0157	0.4	21/64	.3281	8.334	45/64	.7031	17.859
---	.0197	0.5	11/32	.3438	8.731	---	.7087	18
---	.0236	0.6	---	.3543	9	23/32	.7188	18.256
---	.0276	0.7	23/64	.3594	9.128	47/64	.7344	18.653
1/32	.0312	0.794	3/8	.375	9.525	---	.7480	19
---	.0315	0.8	25/64	.3906	9.922	3/4	.750	19.050
---	.0354	0.9	---	.3937	10	49/64	.7656	19.447
---	.0394	1	13/32	.4062	10.319	25/32	.7812	19.844
3/64	.0469	1.191	27/64	.4219	10.716	---	.7874	20
1/16	.0625	1.588	---	.4331	11	51/64	.7969	20.241
5/64	.0781	1.984	7/16	.4375	11.112	13/16	.8125	20.638
---	.0787	2	29/64	.4531	11.509	---	.8268	21
3/32	.0938	2.381	15/32	.4688	11.906	53/64	.8281	21.034
7/64	.1094	2.778	---	.4724	12	27/32	.8438	21.431
---	.1181	3	31/64	.4844	12.303	55/64	.8594	21.828
1/8	.1250	3.175	1/2	.500	12.700	---	.8661	22
9/64	.1406	3.572	---	.5118	13	7/8	.875	22.225
5/32	.1562	3.969	33/64	.5156	13.097	57/64	.8906	22.622
---	.1575	4	17/32	.5312	13.494	---	.9055	23
11/64	.1719	4.366	35/64	.5469	13.891	29/32	.9062	23.019
3/16	.1875	4.762	---	.5512	14	59/64	.9219	23.416
---	.1968	5	9/16	.5625	14.288	15/16	.9375	23.812
13/64	.2031	5.159	37/64	.5781	14.684	---	.9449	24
7/32	.2188	5.556	---	.5905	15	61/64	.9531	24.209
15/64	.2344	5.953	19/32	.5938	15.081	31/32	.9688	24.606
---	.2362	6	39/64	.6094	15.478	---	.9842	25
1/4	.2500	6.350	5/8	.625	15.875	63/64	.9844	25.003
17/64	.2656	6.747	---	.6299	16	1	1.000	25.400
---	.2756	7	41/64	.6406	16.272	---	---	---

To convert millimeters to inches, multiply by 0.0394.

To convert inches to millimeters, multiply by 25.4.

TABLE 4. Drill Sizes for Mounting Hardware

Thread Size	Tap Drill	Clearance Drill
#2-56	#50 (0.0700")	#42 (0.0935")
#4-40	#43 (0.0890")	#31 (0.1200")
#6-32	#36 (0.1065")	#25 (0.1495")
#6-40	#33 (0.1130")	#25 (0.1495")
#8-32	#29 (0.1360")	#16 (0.1770")
#10-24	#25 (0.1495")	#7 (0.2010")
#10-32	#21 (0.1590")	#7 (0.2010")
#1/4"-20	#7 (0.2010")	#H (0.2660")
#5.16"-24	#I (0.2720")	#Q (0.3320")
#3/8"-32	11/32 (0.3438")	25/64" (0.3906")
#7/16"-20	25/64" (0.3906")	15/32" (0.4687")
#1/2"-14 NPSM	23/32" (0.7188")	55/64" (0.8594")
#1/2"-32	15/32" (0.4688")	17/32"(0.5312")

Thread Size	Tap Drill	Clearance Drill
M2.5 x 0.45	2.05mm (0.0807") or #46 (0.0810")	2.9mm (0.1142") or #32 (0.1160")
M3 x 0.5	2.50mm (0.0984") or #39 (0.0995")	3.4mm (0.1339") or #29 (0.1360")
M4 x 0.7	3.30mm (0.1299") or #29 (0.1360")	4.5mm (0.1772") #15 (0.1800")
M6 x 0.75	5.00mm (0.1969") or #8 (0.1990")	6.6mm (0.2598") or #G (0.2610")
M18 x 1	15.5mm (0.6102") or 39/64" (0.6094")	20.0mm (0.7874") or 51/64" (0.7969")
M30 x 1.5	26.5 mm (1.0433") or 1-3/64" (1.0469")	33.0mm (1.2992") or 1-5/16" (1.3125")

TABLE 5. Velocity Conversion

1		2		3		4	
Feet/minute	Meters/ minute	Inches/ minute	Millimeters/ minute	Inches/ second	Millimeters/ second	Seconds/ inch	Seconds/ millimeter
.5	.152	6	152.4	.10	2.540	10.0	.394
1	.305	12	304.8	.20	5.080	5.0	.197
2	.610	24	609.6	.40	10.16	2.50	.098
3	.914	36	914.4	.60	15.24	1.67	.0656
4	1.22	48	1219.2	.80	20.32	1.25	.0492
5	1.52	60	1524.0	1.0	25.40	1.00	.0394
6	1.83	72	1828.8	1.2	30.48	.833	.0328
7	2.13	84	2133.6	1.4	35.56	.714	.0281
8	2.44	96	2438.4	1.6	40.64	.625	.0246
9	2.74	108	2743.2	1.8	45.72	.555	.0219
10	3.05	120	3048.0	2.0	50.8	.500	.0197
11	3.35	132	3352.8	2.2	55.88	.455	.0179
12	3.66	144	3657.6	2.4	60.96	.417	.0164
13	3.96	156	3962.4	2.6	66.04	.385	.0151
14	4.27	168	4267.2	2.8	71.12	.357	.0141
15	4.57	180	4572.0	3.0	76.20	.333	.0131
16	4.88	192	4876.8	3.2	81.28	.313	.0123
17	5.18	204	5181.6	3.4	86.36	.294	.0116
18	5.49	216	5486.4	3.6	91.44	.278	.0109
19	5.79	228	5791.2	3.8	96.52	.263	.0104
20	6.10	240	6096.0	4.0	101.6	.250	.00984
21	6.40	252	6400.8	4.2	106.7	.238	.00937
22	6.71	264	6705.6	4.4	111.8	.227	.00895
23	7.01	276	7010.4	4.6	116.8	.217	.00856
24	7.31	288	7315.2	4.8	121.9	.208	.00820
25	7.62	300	7620.0	5.0	127.0	.200	.00787
30	9.14	360	9144.0	6.0	152.4	.167	.00656
40	12.19	480	12192	8.0	203.2	.125	.00492
50	15.24	600	15240	10	254.0	.100	.00394
60	18.29	720	18288	12	304.8	.083	.00328
70	21.34	840	21336	14	355.6	.071	.00281
80	24.38	960	24384	16	406.4	.063	.00246
90	27.43	1080	27432	18	457.2	.056	.00219
100	30.48	1200	30480	20	508.0	.050	.00197
125	38.10	1500	38100	25	635.0	.040	.00157
150	45.72	1800	45720	30	762.0	.033	.00131
175	53.34	2100	53340	35	889.0	.029	.00112
200	60.96	2400	60960	40	1016	.025	.00098
225	68.58	2700	68580	45	1143	.022	.00087
250	76.20	3000	76200	50	1270	.020	.00079
275	83.82	3300	83820	55	1397	.018	.00072
300	91.44	3600	91440	60	1524	.016	.00066
325	99.06	3900	99060	65	1651	.015	.00061
350	106.7	4200	106680	70	1778	.014	.00056
375	114.3	4500	114300	75	1905	.013	.00052
400	121.9	4800	121920	80	2032	.012	.00049
450	137.2	5400	137160	90	2286	.011	.00044
500	152.4	6000	152400	100	2540	.010	.00039
600	182.9	7200	182880	120	3048	.0083	.00033
700	213.4	8400	213360	140	3556	.0071	.00028
800	243.8	9600	243840	160	4064	.0063	.00025
900	274.3	10800	274320	180	4572	.0055	.00022
1000	304.8	12000	304800	200	5080	.0050	.000197
1250	381.0	15000	381000	250	6350	.0040	.000157
1665	507.5	19980	507492	333	8458	.0030	.000118
2500	762.0	30000	762000	500	12700	.0020	.000079
5000	1524	60000	1524000	1000	25400	.0010	.000039

TABLE 6. Velocity Conversion Factors

From: \ To:	Miles/ hour	Feet/ minute	Inches/ minute	Meters/ minute	Centimeters/ minute	Feet/ second	Inches/ second	Meters/ second	Millimeters/ second
1 mile/ hour	1.0	88	1056	26.822	2682.24	1.4667	17.60	0.4470	447.0
1 foot/ minute	$1.1364x10^{-2}$	1.0	12.0	0.3048	30.48	$1.6667x10^{-2}$	20.000	$5.08x10^{-3}$	5.08
1 inch/ minute	$9.470x10^{-4}$	$8.333x10^{-2}$	1.0	$2.540x10^{-2}$	2.54	$1.3888x10^{-3}$	$1.6666x10^{-2}$	$4.23x10^{-4}$	0.0423
1 meter/ minute	$3.7282x10^{-2}$	3.281	39.372	1.0	100.0	$5.468x10^{-2}$	0.6562	$1.667x10^{-2}$	16.667
1 centi- meter/ minute	$3.7282x10^{-4}$	$3.281x10^{-2}$	0.3937	0.01	1.0	$5.468x10^{-4}$	$6.5616x10^{-3}$	$1.667x10^{-4}$	0.1667
1 foot/ second	0.6818	60	720	18.29	1829	1.0	12	0.3048	304.8
1 inch/ second	$5.6818x10^{-2}$	5	60	1.524	152.4	$8.333x10^{-2}$	1.0	$2.540x10^{-2}$	25.40
1 meter/ second	2.2369	196.85	2362.2	60.0	6000.0	3.281	39.372	1.0	1000
1 milli- meter/ second	$2.2369x10^{-3}$	0.1969	2.3622	$6.0x10^{-2}$	6.000	$3.281x10^{-3}$	$3.937x10^{-2}$	$1x10^{-3}$	1.0

TABLE 7. Length Conversion Factors

From: \ To:	Angstroms	Milli- meters	Centi- meters	Inches	Feet	Yards	Meters	Kilo- meters	Miles (imperial)
1 Angstrom (Å)	1.0	$1.0x10^{-7}$	$1.0x10^{-8}$	$3.937x10^{-9}$	$3.2808x10^{-10}$	$1.0936x10^{-10}$	$1.0x10^{-10}$	$1.0x10^{-13}$	$6.2137x10^{-14}$
1 millimeter (mm)	$1.0x10^{7}$	1.0	0.1	0.0394	$3.2808x10^{-3}$	$1.0936x10^{-3}$	$1.0x10^{-3}$	$1.0x10^{-6}$	$6.2137x10^{-7}$
1 centimeter (cm)	$1.0x10^{8}$	10.0	1.0	0.3937	0.0328	0.0109	0.01	$1.0x10^{-5}$	$6.2137x10^{-6}$
1 inch (in)	$2.54x10^{8}$	25.4	2.54	1.0	0.0833	0.0278	0.0254	$2.54x10^{-5}$	$1.5783x10^{-5}$
1 foot (ft)	$3.048x10^{9}$	304.8	30.48	12.0	1.0	0.3333	0.3048	$3.048x10^{-4}$	$1.8939x10^{-4}$
1 yard (yd)	$9.144x10^{9}$	914.4	91.44	36.0	3.0	1.0	0.9144	$9.144x10^{-4}$	$5.6818x10^{-4}$
1 meter (m)	$1.0x10^{10}$	$1.0x10^{3}$	100.0	39.3701	3.2808	1.0936	1.0	$1.0x10^{-3}$	$6.2137x10^{-4}$
1 kilometer (km)	$1.0x10^{13}$	$1.0x10^{6}$	$1.0x10^{5}$	$3.937x10^{4}$	$3.2808x10^{3}$	$1.0936x10^{3}$	$1.0x10^{3}$	1.0	0.6214
1 mile (imperial)	$1.6093x10^{13}$	$1.6093x10^{6}$	$1.6093x10^{5}$	$6.336x10^{4}$	$5.280x10^{3}$	$1.760x10^{3}$	$1.6093x10^{3}$	1.6093	1.0

TABLE 8. Temperature Conversion: °C ⟷ °F

Celsius°	Fahrenheit°	Celsius°	Fahrenheit°	Celsius°	Fahrenheit°
-62	-80	0.0	32	22.2	72
-57	-70	0.6	33	22.8	73
-51	-60	1.1	34	23.3	74
-46	-50	1.7	35	23.9	75
-40	-40	2.2	36	24.4	76
-34	-30	2.8	37	25.0	77
-29	-20	3.3	38	25.6	78
-23	-10	3.9	39	26.1	79
-17.8	0	4.4	40	26.7	80
-17.2	1	5.0	41	27.2	81
-16.7	2	5.6	42	27.8	82
-16.1	3	6.1	43	28.3	83
-15.6	4	6.7	44	28.9	84
-15.0	5	7.2	45	29.4	85
-14.4	6	7.8	46	30.0	86
-13.9	7	8.3	47	30.6	87
-13.3	8	8.9	48	31.1	88
-12.8	9	9.4	49	31.7	89
-12.2	10	10.0	50	32.2	90
-11.7	11	10.6	51	32.8	91
-11.1	12	11.1	52	33.3	92
-10.6	13	11.7	53	33.9	93
-10.0	14	12.2	54	34.4	94
-9.4	15	12.8	55	35.0	95
-8.9	16	13.3	56	35.6	96
-8.3	17	13.9	57	36.1	97
-7.8	18	14.4	58	36.7	98
-7.2	19	15.0	59	37.2	99
-6.7	20	15.6	60	37.8	100
-6.1	21	16.1	61	43	110
-5.6	22	16.7	62	49	120
-5.0	23	17.2	63	54	130
-4.4	24	17.8	64	60	140
-3.9	25	18.3	65	66	150
-3.3	26	18.9	66	71	160
-2.8	27	19.4	67	77	170
-2.2	28	20.0	68	82	180
-1.7	29	20.6	69	88	190
-1.1	30	21.1	70	93	200
-0.6	31	21.7	71	100	212

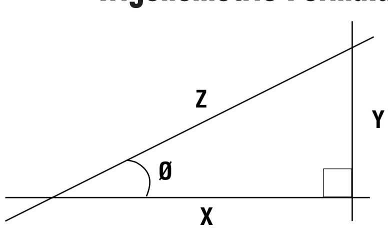
NOTE: For temperatures not given in the table, use the conversion information at the right.

Temperature Scale	Water Boiling Point	Water Freezing Point	To Convert Scales:
°F (Fahrenheit)	212°F	32°F	°F = (°C x $^9/_5$) + 32
°C (Celsius or Centigrade)	100°F	0°C	°C = (°F - 32) x $^5/_9$

TABLE 9. Trigonometric Functions and Formulas

Degrees	sin	cos	tan	cot	sec	csc	
0	0.0000	1.0000	0.0000	–	1.0000	–	90
1	0.0174	0.9998	0.0175	57.290	1.0002	57.299	89
2	0.0349	0.9994	0.0349	28.636	1.0006	28.654	88
3	0.0523	0.9986	0.0524	19.081	1.0014	19.107	87
4	0.0698	0.9976	0.0699	14.301	1.0024	14.336	86
5	0.0872	0.9962	0.0875	11.430	1.0038	11.474	85
6	0.1045	0.9945	0.1051	9.5144	1.0055	9.5668	84
7	0.1219	0.9925	0.1228	8.1443	1.0075	8.2055	83
8	0.1392	0.9903	0.1405	7.1154	1.0098	7.1853	82
9	0.1564	0.9877	0.1584	6.3138	1.0125	6.3924	81
10	0.1736	0.9848	0.1763	5.6713	1.0154	5.7588	80
11	0.1908	0.9816	0.1944	5.1446	1.0187	5.2408	79
12	0.2079	0.9781	0.2126	4.7046	1.0223	4.8097	78
13	0.2250	0.9744	0.2309	4.3315	1.0263	4.4454	77
14	0.2419	0.9703	0.2493	4.0108	1.0306	4.1336	76
15	0.2588	0.9659	0.2679	3.7320	1.0353	3.8637	75
16	0.2756	0.9613	0.2867	3.4874	1.0403	3.6280	74
17	0.2924	0.9563	0.3057	3.2708	1.0457	3.4203	73
18	0.3090	0.9511	0.3249	3.0777	1.0515	3.2361	72
19	0.3256	0.9455	0.3443	2.9042	1.0576	3.0715	71
20	0.3420	0.9397	0.3640	2.7475	1.0642	2.9238	70
21	0.3584	0.9336	0.3839	2.6051	1.0711	2.7904	69
22	0.3746	0.9272	0.4040	2.4751	1.0785	2.6695	68
23	0.3907	0.9205	0.4245	2.3558	1.0864	2.5593	67
24	0.4067	0.9135	0.4452	2.2460	1.0946	2.4586	66
25	0.4226	0.9063	0.4663	2.1445	1.1034	2.3662	65
26	0.4384	0.8988	0.4877	2.0503	1.1126	2.2812	64
27	0.4540	0.8910	0.5095	1.9626	1.1223	2.2027	63
28	0.4695	0.8829	0.5317	1.8807	1.1326	2.1300	62
29	0.4848	0.8746	0.5543	1.8040	1.1434	2.0627	61
30	0.5000	0.8660	0.5774	1.7320	1.1547	2.0000	60
31	0.5150	0.8572	0.6009	1.6643	1.1666	1.9416	59
32	0.5299	0.8580	0.6249	1.6003	1.1792	1.8871	58
33	0.5446	0.8387	0.6494	1.5399	1.1924	1.8361	57
34	0.5592	0.8290	0.6745	1.4826	1.2062	1.7883	56
35	0.5736	0.8192	0.7002	1.4281	1.2208	1.7434	55
36	0.5878	0.8090	0.7265	1.3764	1.2361	1.7013	54
37	0.6018	0.7986	0.7536	1.3270	1.2521	1.6616	53
38	0.6157	0.7880	0.7813	1.2799	1.2690	1.6243	52
39	0.6293	0.7771	0.8098	1.2349	1.2868	1.5890	51
40	0.6428	0.7660	0.8391	1.1918	1.3054	1.5557	50
41	0.6561	0.7547	0.8693	1.1504	1.3250	1.5242	49
42	0.6691	0.7431	0.9004	1.1106	1.3456	1.4945	48
43	0.6820	0.7314	0.9325	1.0724	1.3673	1.4663	47
44	0.6947	0.7193	0.9567	1.0355	1.3902	1.4396	46
45	0.7071	0.7071	1.0000	1.0000	1.4142	1.4142	45
Degrees	**cos**	**sin**	**cot**	**tan**	**csc**	**sec**	**Degrees**

Trigonometric Formulas for Distance or Angle Calculation



Relationships:

sin ø = Y/Z
cos ø = X/Z
tan ø = X/Y
csc ø = Z/Y = 1/sin ø
sec ø = Z/X = 1/cos ø
cot ø = X/Y = 1/tan ø

Given ø and X:	Y = X tan ø	Z = X sec ø
Given ø and Y:	X = Y cot ø	Z = Y csc ø
Given ø and Z:	X = Z cos ø	Y = Z sin ø
Given X and Y:	Z = $\sqrt{X^2 + Y^2}$	ø = arctan (Y/X)

Basic Electrical Formulas

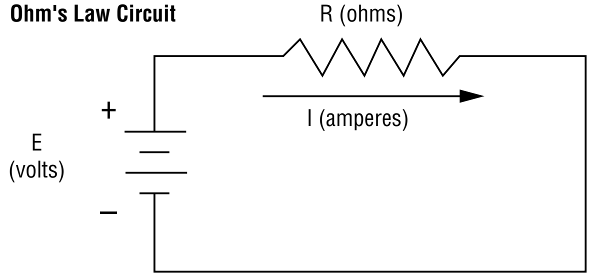
Ohm's Law describes the relationship between voltage, resistance, and current in electrical circuits. As stated by Ohm's Law, the current in the figure below is directly proportional to the applied voltage and inversely proportional to the resistance of the circuit. This relationship, in the form of an equation, is written as follows:

$$I = \frac{E}{R}$$

where **I** is the current (in amperes), **E** is the electromotive force (in volts), and **R** is the resistance (in ohms). It follows that:

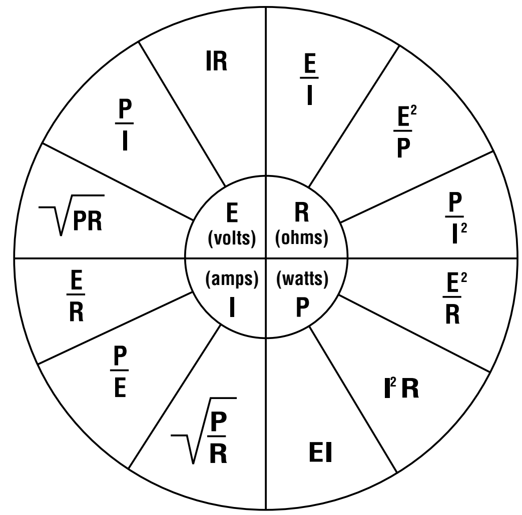
$$E = I \times R \quad \text{and} \quad R = \frac{E}{I}$$

Ohm's Law Circuit



As an example, if R=100 ohms and E=10 volts, then the current in the circuit is equal to:

$$I = \frac{10}{100} \quad \text{or } 1/10 \text{ amp, or 100 milliamps}$$



Electrical power may also be quantified in terms of a single equation. Power is the rate of doing work, and is measured in units called *watts*. Watts are equal to *voltage x current. DC power equations* relate power (in watts), current (in amperes), and resistance (in ohms), as follows:

$$P = E \times I \qquad P = \frac{E^2}{R} \qquad P = I^2 \times R$$

As an example, if R = 1000 ohms and E = 10 volts, the power used in the circuit is:

$$P = \frac{E^2}{R} = \frac{100}{1000} = 1/10 \text{ watt} = 100 \text{ milliwatts}$$

TABLE 10. Resistor Color Codes

Color	Digit	Multiplier	Tolerance
black	0	1	±1%
brown	1	10	±2%
red	2	100	±3 %
orange	3	1000	±4%
yellow	4	10000	
green	5	100000	
blue	6	1000000	
violet	7	10000000	
gray	8	100000000	
white	9		
gold		0.1	±5%
silver		0.01	±10%
no color			±20%

The colored bands on the bodies of resistors denote their *value* (in ohms), and their *tolerance* (in ±%). With the resistor positioned as shown below, the first two color bands are digits ,the next is the multiplier, and the next (if present) is the tolerance.

As an example ,a resistor color-coded YELLOW-VIOLET-BROWN-GOLD would be 47 x 10, ±5% tolerance or: 470 ohms (±5% tolerance).

Precision resistors usually have their values stamped on the resistor body. Some film-type resistors may have three significant figures and, therefore, use five color bands (including *3* digit bands and 1 multiplier band).

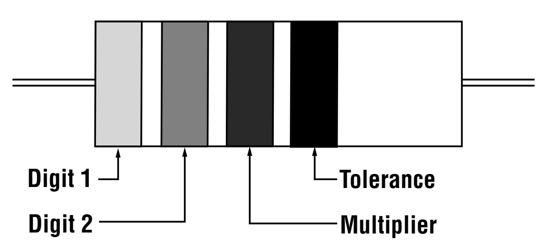


TABLE 11. Copper Wire Information

AWG	Solid Wire Diameter American Wire or Brown and Sharpe Gage		Approximate Stranded Wire Diameter[1]		Approximate Resistance per 100 feet (30 meters)[2]
	Inches	Millimeters	Inches	Millimeters	Ohms
0000	.4601	11,687	.522	13.26	.0050
000	.4097	10.406	.464	11.79	.0060
00	.3648	9.266	.414	10.52	.0080
0	.3249	8.252	.368	9.35	.010
1	.2893	7.348	.328	8.33	.012
2	.2576	6.543	.292	7.42	.016
3	.2294	5.827			.020
4	.2043	5.189	.232	5.89	.025
5	.1819	4.620			.030
6	.1620	4.115	.184	4.67	.040
7	.1443	3.665			.050
8	.1285	3.264	.147	3.73	.060
9	.1144	2.906			.080
10	.1019	2.588	.116	2.95	.10
11	.0907	2.304			.13
12	.0808	2.052	.095	2.41	.16
13	.0720	1.829			.20
14	.0641	1.628	.073	1.85	.25
15	.0571	1.450			.32
16	.0508	1.290	.059	1.50	.40
17	.0453	1.151			.50
18	.0403	1.024	.048	1.22	.64
19	.0359	0.912			.80
20	.0320	0.813	.036	0.91	1.0
21	.0285	0.724			1.3
22	.0253	0.643	.030	0.76	1.6
23	.0226	0.574			2.0
24	.0201	0.511	.024	0.61	2.6
25	.0179	0.455			3.2
26	.0159	0.404	.020	0.51	4.1
27	.0142	0.361	.018	0.46	5.2
28	.0126	0.320	.015	0.38	6.5
29	.0113	0.287			8.2
30	.0100	0.254	.012	0.30	10
31	.00892	0.227			13
32	.00795	0.202	.008	0.20	16
33	.00708	0.180			20
34	.00630	0.160	.007	0.18	26
35	.00561	0.142			33
36	.00500	0.127	.006	0.15	42
37	.00445	0.113			52
38	.00396	0.101			66
39	.00353	0.090			83
40	.00314	0.080			105
41	.00280	0.071			130
42	.00249	0.063			170
43	.00222	0.056			210
44	.00198	0.050			270
45	.00176	0.045			330
46	.00157	0.040			420

[1] Exact diameter is dependent upon the wire gage used for the strands. Diameter listed represents the most common wire type for AWG.

[2] Resistance values assume the resistivity of solid copper wire. Stranding and/or copper alloy increase the resistance values.

TABLE 12. Hazardous Location Classifications per National Electrical Code (NEC) Article 500

CLASS	DIVISION	GROUP
CLASS I Locations in which flammable gases or vapors are (or may be) present in the air in quantities great enough to produce explosive or ignitable mixtures.	**DIVISION 1:** Locations in which hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal conditions. -or- Locations in which hazardous concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage. -or- Locations in which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors. **DIVISION 2:** Locations in which volatile flammable liquids or flammable gases are handled, processed, or used, but are normally kept in closed containers and can only escape due to accidental rupture. -or- Locations in which hazardous concentrations of gases or vapors are normally prevented by mechanical ventilation and might become hazardous due to failure of the ventilating equipment. -or- Locations that are adjacent to Class I, Division 1 locations.	**GROUP A:** Atmospheres containing acetylene **GROUP B:** Atmospheres containing: acrolein (inhibited) butadiene ethylene oxide hydrogen manufactured gases containing more than 30% hydrogen by volume propylene oxide **GROUP C:** Atmospheres containing: allyl alcohol carbon monoxide cyclopropane diethyl ether ethylene hydrogen sulfide methyl ether n-propyl ether or gas or vapors of equivalent hazard **GROUP D:** Atmospheres containing: acetone ammonia benzene butane butyl alcohol ethane ethyl alcohol gasoline heptanes hexanes methane (natural gas) methyl alcohol methyl ethyl ketone (MEK) naphtha octanes pentanes propane styrene toluene xylenes or gas or vapors of equivalent hazard
CLASS II Locations in which there are explosive mixtures of air and combustible dust.	**DIVISION 1:** Locations in which explosive or ignitible amounts of combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions. -or- Locations where mechanical failure or abnormal operation of machinery or equipment might cause explosive or ignitable mixtures to be produced. -or- Locations in which combustible electrically conductive dust is present. **DIVISION 2:** Locations where combustible dust deposits exist but are not likely to be thrown into suspension in the air, but where the dust deposits may be heavy enough to interfere with safe heat dissipation from electric equipment. -or- Locations where combustible dust deposits may be ignited by arcs, sparks, or burning material from electric equipment.	**GROUP E:** Atmospheres containing combustible: metal dusts regardless of resistivity -or- dusts of similarly hazardous characteristics having resistivity of less than 100,000 ohm-centimeter **GROUP F:** atmospheres containing combustible: carbon black, charcoal, or coke dusts which have more than 8% total volatile material -or- carbon black, charcoal, or coke dusts sensitized by other materials so that they present an explosion hazard, and having a resistivity greater than 100 ohm-centimeter but equal to or less than 100,000,000 ohm-centimeter **GROUP G:** Atmospheres containing dusts having resistivity of 100,000,000 ohm-centimeter or greater (nonconductive dusts)
CLASS III Locations in which there is the presence of easily-ignited fibers or flyings, but where the fibers or flyings are not likely to be in suspension in the air in quantities great enough to produce ignitable mixtures.	**DIVISION 1:** Locations in which easily ignitable fibers or materials producing flyings are handled, manufactured, or used. **DIVISION 2:** Locations in which easily ignitable fibers are stored or handled (except in a manufacturing process).	(NOT GROUPED) Manufacturers include: textile mills, clothing plants, fiber processing plants Easily ignitable fibers include: cotton, rayon, sisal, hemp, jute

TABLE 13. NEMA Enclosure Ratings for Nonhazardous Locations

Standard NEMA (IEC)*	Intended Use	Accidental bodily contact	Falling dirt	Dust, lint, fibers (non-volatile)	Windblown dust	Falling liquid, light splash	Hosedown and heavy splash	Rain, snow, and sleet	Ice buildup	Oil or coolant seepage	Oil or coolant spray and splash	Occasional submersion	Prolonged sub-mersion	Corrosive agents
NEMA 1 (IP10)	Indoor	Yes	Yes	...	...	...	...	...	...	...	...	...	...	...
NEMA 2 (IP11)	Indoor	Yes	Yes	...	...	Yes	...	...	...	...	...	...	...	...
NEMA 3 (IP54)	Outdoor	Yes	Yes	Yes	Yes	Yes	...	Yes	...	...	...	...	...	...
NEMA 3S (IP54)	Outdoor	Yes	Yes	Yes	Yes	Yes	...	Yes	Yes	...	...	...	...	...
NEMA 4 (IP56)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	...	...	...
NEMA 4X (IP56)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	...	...	Yes
NEMA 6 (IP67)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	Yes	...	...
NEMA 6P (IP67)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	Yes	Yes	Yes
NEMA 12 (IP52)	Indoor	Yes	Yes	Yes	...	Yes	...	...	...	Yes	...	...	...	...
NEMA 13 (IP54)	Indoor	Yes	Yes	Yes	...	Yes	...	...	...	Yes	Yes	...	...	...

*The IEC equivalents listed in this column are approximate: NEMA types *meet or exceed* the test requirements for the associated IEC classifications.

TABLE 14. IP Enclosure Ratings for Nonhazardous Locations

1ST CHARACTERISTIC: Protection against contact and penetration of solid bodies	
Numeral	**Short Description**
0	Non-protected
1	Protected against solid objects greater than 50 mm
2	Protected against solid objects greater than 12 mm
3	Protected against solid objects greater than 2.5 mm
4	Protected against solid objects greater than 1.0 mm
5	Dust protected
6	Dust-tight

2ND CHARACTERISTIC: Protection against the penetration of liquids	
Numeral	**Short Description**
0	Non-protected
1	Protected against dripping water
2	Protected against dripping water when tilted up to 15°
3	Protected against spraying water
4	Protected against splashing water
5	Protected against water jets
6	Protected against heavy seas
7	Protected against the effects of immersion
8	Protected against submersion

TABLE 15. Relative Chemical Resistance of Sensor Housing Materials and Lenses

Housing Material	RESISTANCE TO: Industrial Solvents	Dilute Acids	Concentrated Acids	Dilute Caustic Alkalis	Concentrated Caustic Alkalis	10% Sodium Hydroxide in Steam	Sunlight and Weathering
Thermoplastic Polyester	**FAIR** Attacked by: acetone, MEK, and methylene chloride	EXCELLENT	GOOD	POOR	POOR	POOR	GOOD
Lexan® Polycarbonate	**POOR** Attacked by: acetone, MEK, and methylene chloride	GOOD	FAIR	POOR	POOR	POOR	GOOD
NORYL® Polyphenylene oxide (PPO)	**FAIR** Attacked by: chlorinated hydrocarbons[1]	GOOD	FAIR	EXCELLENT	GOOD	GOOD	EXCELLENT
Delrin® Acetal	GOOD	FAIR	POOR	FAIR	POOR	FAIR	GOOD
Epoxy-coated zinc-aluminumalloy	GOOD	GOOD	FAIR	GOOD	FAIR	FAIR	EXCELLENT
Anodized aluminum	EXCELLENT	FAIR	POOR	GOOD	FAIR	FAIR	GOOD
Stainless steel	EXCELLENT	FAIR	POOR	EXCELLENT	GOOD	GOOD	GOOD
PVC (Polyvinyl- chloride)	**FAIR** Attacked by: acetone, MEK, and methylene chloride	GOOD	FAIR	EXCELLENT	EXCELLENT	EXCELLENT	GOOD
Polyethylene	**FAIR** Attacked by: chlorinated hydrocarbons[1]	EXCELLENT	EXCELLENT	GOOD	GOOD	GOOD	POOR
Cycolac® ABS	**POOR** Attacked by: acetone, MEK, esters, ketones, & some chlorinated hydrocarbons	GOOD	POOR	GOOD	GOOD	GOOD	FAIR
Lens Material	**Industrial Solvents**	**Dilute Acids**	**Concentrated Acids**	**Dilute Caustic Alkalis**	**Concentrated Caustic Alkalis**	**10% Sodium Hydroxide in Steam**	**Sunlight and Weathering**
Glass[2]	EXCELLENT	GOOD	FAIR	EXCELLENT	GOOD	GOOD	EXCELLENT
Acrylic[3]	POOR	FAIR	POOR	GOOD	FAIR	FAIR	GOOD
Polysulfone	**FAIR** Attacked by: chlorinated hydrocarbons[3]	FAIR	POOR	FAIR	POOR	POOR	POOR
Lexan® Polycarbonate	**POOR** (see **Lexan**®, above)	GOOD	FAIR	POOR	POOR	POOR	GOOD

Key to Performance

Rating	Percent Retention to Strength	Degree of Attack
Excellent	85 to 100%	Slight (or no) attack
Good	75 to 84%	Moderate attack
Fair	50 to 74%	Noticeable swelling, softening, etching, or corrosion
Poor	<50%	Severe degradation

NOTES:

NOTE 1: Chlorinated hydrocarbons include Freon, methylene chloride, trichlorethane, and trichloroethylene.

NOTE 2: Plastic lens covers are available for some sensors to meet FDA requirements.

NOTE 3: Glass covers are available for some sensors to protect the acrylic lens.