



OPT210

# MONOLITHIC PHOTODIODE AND AMPLIFIER 300kHz Bandwidth at $R_F = 1M\Omega$

## FEATURES

- **BOOTSTRAP ANODE DRIVE:**  
Extends Bandwidth: 900kHz ( $R_F = 100K\Omega$ )  
Reduces Noise
- **LARGE PHOTODIODE: 0.09" x 0.09"**
- **HIGH RESPONSIVITY: 0.45A/W (650nm)**
- **EXCELLENT SPECTRAL RESPONSE**
- **WIDE SUPPLY RANGE:  $\pm 2.25$  to  $\pm 18V$**
- **TRANSPARENT DIP, SIP AND SURFACE-MOUNT PACKAGES**

## APPLICATIONS

- **BARCODE SCANNERS**
- **MEDICAL INSTRUMENTATION**
- **LABORATORY INSTRUMENTATION**
- **POSITION AND PROXIMITY DETECTORS**
- **PARTICLE DETECTORS**

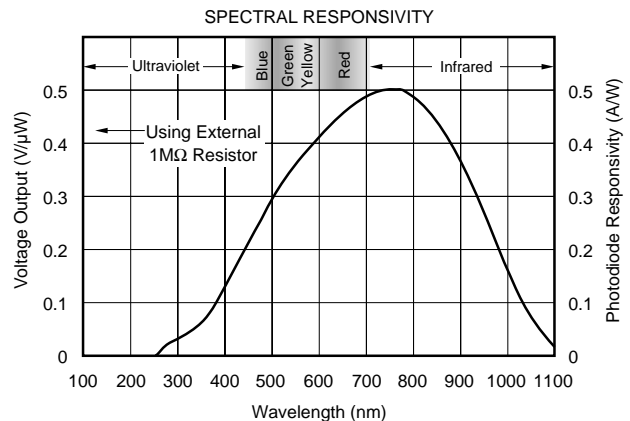
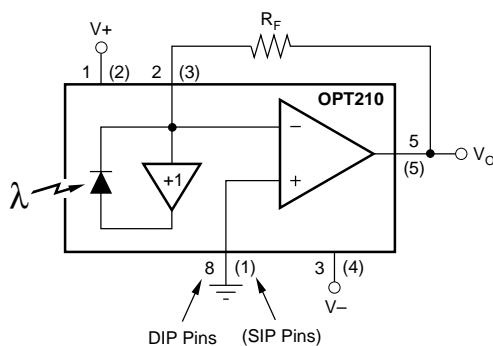
## DESCRIPTION

The OPT210 is a photodetector consisting of a high performance silicon photodiode and precision FET-input transimpedance amplifier integrated on a single monolithic chip. Output is an analog voltage proportional to light intensity.

The large 0.09" x 0.09" photodiode is operated at low bias voltage for low dark current and excellent linearity. A novel photodiode anode bootstrap circuit reduces the effects of photodiode capacitance to extend bandwidth and reduces noise.

The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered with discrete designs such as leakage current errors, noise pick-up and gain peaking due to stray capacitance.

The OPT210 operates from  $\pm 2.25$  to  $\pm 18V$  supplies and quiescent current is only 2mA. Available in a transparent 8-pin DIP, 8-lead surface-mount and 5-pin SIP, it is specified for 0° to 70°C operation.



# SPECIFICATIONS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $\lambda = 650\text{nm}$ , External  $R_F = 1\text{M}\Omega$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

PARAMETER	CONDITIONS	OPT210P OPT210W			UNITS
		MIN	TYP	MAX	
<b>RESPONSIVITY</b> Photodiode Current Unit-to-Unit Variation Voltage Output Nonlinearity Photodiode Area	$\lambda = 650\text{nm}$  $\lambda = 650\text{nm}$ , External $R_F = 1\text{M}\Omega$  (0.09 x 0.09in) (2.29 x 2.29mm)		0.45 $\pm 5$ 0.45 0.01 0.008 5.2		A/W % V/ $\mu\text{W}$ % of FS in <sup>2</sup> mm <sup>2</sup>
<b>DARK ERROR, RTO</b> Offset Voltage vs Temperature vs Power Supply Voltage Noise	   $V_S = \pm 2.25\text{V}$ to $\pm 18\text{V}$ BW = 0.01Hz to 100kHz		$\pm 2$ $\pm 35$ 100 160	$\pm 10$  1000	mV $\mu\text{V}/^\circ\text{C}$ $\mu\text{V}/\text{V}$ $\mu\text{Vrms}$
<b>FREQUENCY RESPONSE</b> Bandwidth Rise Time Settling Time, 1% 0.1% 0.01% Overload Recovery	External $R_F = 1\text{M}\Omega$ 10% to 90% FS to Dark step   100% Overdrive		300 1.2 3 8 20 7		kHz $\mu\text{s}$ $\mu\text{s}$ $\mu\text{s}$ $\mu\text{s}$ $\mu\text{s}$
<b>OUTPUT</b> Voltage Output, Positive Positive Negative <sup>(1)</sup> Capacitive Load, Stable Operation Short-Circuit Current <sup>(2)</sup>	$R_L = 10\text{k}\Omega$ $R_L = 5\text{k}\Omega$ $R_L = 10\text{k}\Omega$	(V+)-1.25  -0.4	(V+)-0.75 (V+)-1 -0.5 500 +50		V V pF mA
<b>POWER SUPPLY</b> Operating Range Quiescent Current		$\pm 2.25$	+2.0/-1.7	$\pm 18$ $\pm 4$	V mA
<b>TEMPERATURE RANGE</b> Specification Operating Storage $\theta_{JA}$		0 0 -25		70 70 85	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}/\text{W}$

NOTES: (1) Output typically swings to 0.5V below the voltage applied to the non-inverting input terminal, which is normally connected to ground. (2) Positive current (sourcing) is limited. Negative current (sinking) is not limited.

# PHOTODIODE SPECIFICATIONS

PARAMETER	CONDITIONS	PHOTODIODE			UNITS
		MIN	TYP	MAX	
Photodiode Area	(0.09 x 0.09in) (2.29 x 2.29mm)		0.008 5.2		in <sup>2</sup> mm <sup>2</sup>
Current Responsivity	$\lambda = 650\text{nm}$		0.45 865		A/W $\mu\text{A}/\text{W}/\text{cm}^2$
Dark Current vs Temperature	$V_D = -1.2\text{V}$		70 Doubles every $10^\circ\text{C}$		pA
Capacitance	$V_D = -1.2\text{V}$		550		pF
Effective Capacitance <sup>(1)</sup>	$V_D = -1.2\text{V}$		10		pF

NOTES: (1) Effect of photodiode capacitance is reduced by internal buffer bootstrap drive. See text

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# OP AMP SPECIFICATIONS

Op amp specifications provided for comparative information only.

PARAMETER	CONDITIONS	OP AMP			UNITS
		MIN	TYP	MAX	
<b>INPUT</b> Offset Voltage vs Temperature vs Power Supply Input Bias Current Inverting Input vs Temperature Non-inverting Input			±2 ±35 100  15 Doubles every 10°C 300		mV μV/°C μV/V  pA μA
<b>NOISE</b> Voltage Noise f = 10Hz f = 100Hz f = 1kHz Current Noise Density, Inverting Input	BW = 0.01Hz to 100kHz		20 9 6 0.8		nV/√Hz nV/√Hz nV/√Hz fA/√Hz
<b>INPUT VOLTAGE RANGE</b> Common-Mode Input Range <sup>(1)</sup> Common-Mode Rejection			V <sub>S</sub> ±2.25 65		V dB
<b>INPUT IMPEDANCE</b> Inverting Input Impedance Non-Inverting Input Impedance			3x10 <sup>10</sup>   3 250		Ω    pF kΩ
<b>OPEN-LOOP GAIN</b> Open-Loop Voltage Gain	V <sub>O</sub> = 0V to +13.75V		70		dB
<b>FREQUENCY RESPONSE</b> Bandwidth, Small Signal Rise Time, Large Signal Settling Time, 1% 0.1% 0.01% Overload Recovery	10% to 90% 10V step   100% Overdrive		35 25 240 390 800 7		MHz ns ns ns ns μs
<b>OUTPUT</b> Voltage Output, Positive Positive Negative <sup>(1)</sup> Capacitive Load, Stable Operation Short-Circuit Current <sup>(2)</sup>	R <sub>L</sub> = 10kΩ R <sub>L</sub> = 5kΩ R <sub>L</sub> = 10kΩ	(V+)-1.25  -0.4	(V+)-0.75 (V+)-1 -0.5 500 +50		V V pF mA
<b>POWER SUPPLY</b> Operating Voltage Quiescent Current		±2.25	+1.7/-1.4	±18 ±4	V mA

NOTES: (1) Output typically swings to 0.5V below the voltage applied to the non-inverting input terminal, which is normally connected to ground. (2) Positive current (sourcing) is limited. Negative current (sinking) is not limited.

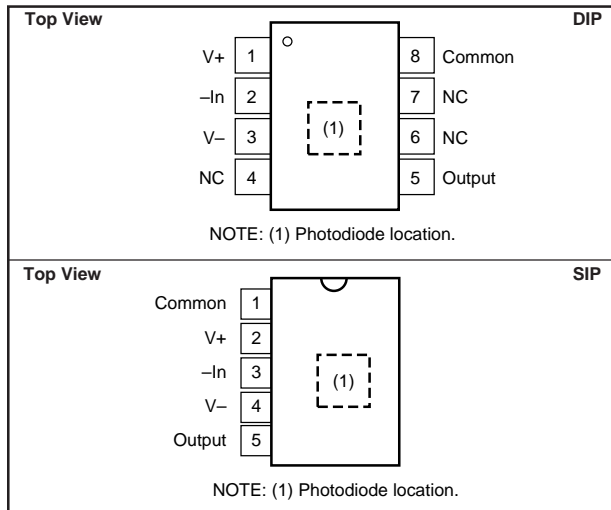
# BUFFER SPECIFICATIONS

Buffer specifications provided for comparative information only.

PARAMETER	CONDITIONS	BUFFER			UNITS
		MIN	TYP	MAX	
<b>INPUT</b> Offset Voltage <sup>(1)</sup> Input Bias Current vs Temperature Input Impedance			-1.2 15 Doubles every 10°C 10 <sup>11</sup>   3		V pA  Ω    pF
<b>FREQUENCY RESPONSE</b> Bandwidth, Small Signal			500		MHz
<b>OUTPUT</b> Current Voltage Gain			±200 0.99		μA V/V
<b>POWER SUPPLY</b> Operating Range Quiescent Current		±2.25	±0.3	±18	V mA

NOTE: (1) Intentional voltage offset to reverse bias photodiode.

## PIN CONFIGURATIONS



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±18V
Input Voltage Range (Common Pin)	±V <sub>S</sub>
Output Short-Circuit (to ground)	Continuous
Operating Temperature: P, W	-25°C to +85°C
Storage Temperature: P, W	-25°C to +85°C
Junction Temperature: P, W	+85°C
Lead Temperature (soldering, 10s)	+300°C
(Vapor-Phase Soldering Not Recommended on Plastic Packages)	

## PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
OPT210P	8-Pin Plastic DIP	006-5
OPT210P-J	8-Lead Surface Mount <sup>(2)</sup>	006-6
OPT210W	5-Pin Plastic SIP	321-1

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book. (2) 8-pin DIP with leads formed for surface mounting.



## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.



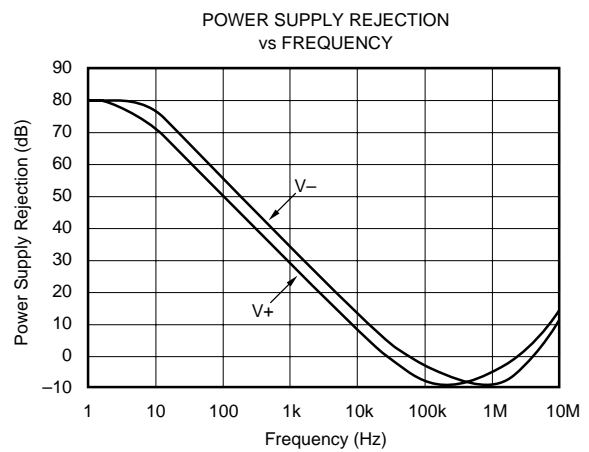
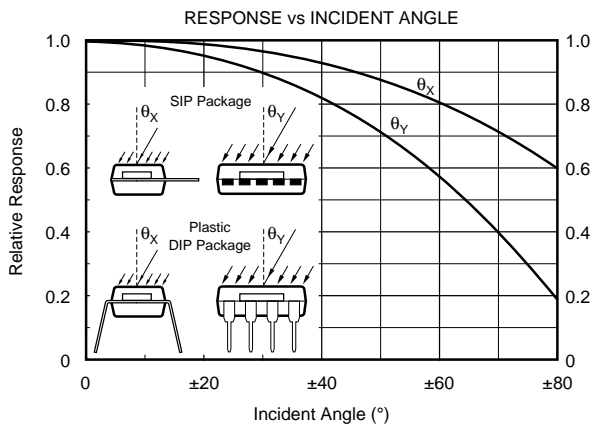
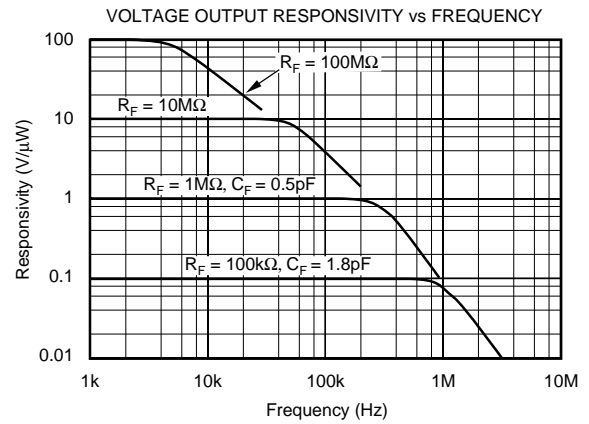
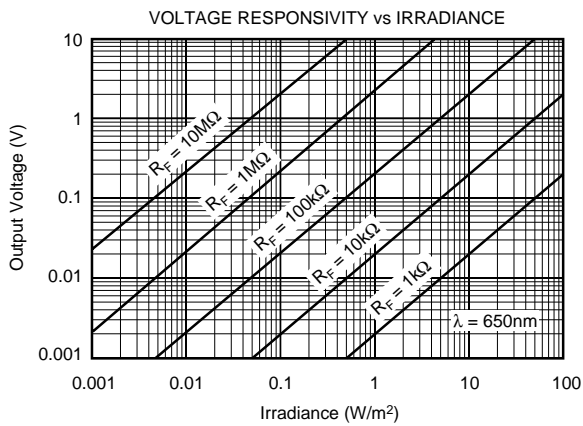
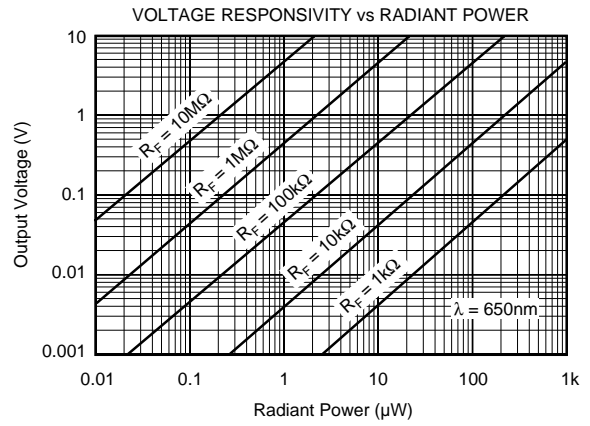
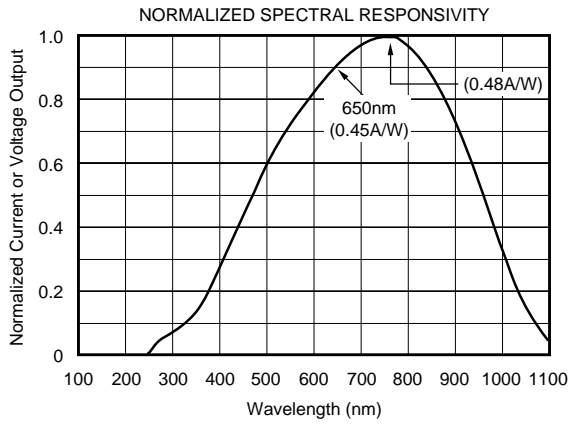
## MOISTURE SENSITIVITY AND SOLDERING

Clear plastic does not contain the structural-enhancing fillers used in black plastic molding compound. As a result, clear plastic is more sensitive to environmental stress than black plastic. This can cause difficulties if devices have been stored in high humidity prior to soldering. The rapid heating during soldering can stress wire bonds and cause failures. Prior to soldering, it is recommended that plastic devices be baked-out at 85°C for 24 hours.

The fire-retardant fillers used in black plastic are not compatible with clear molding compound. The OPT210 plastic packages cannot meet flammability test, UL-94.

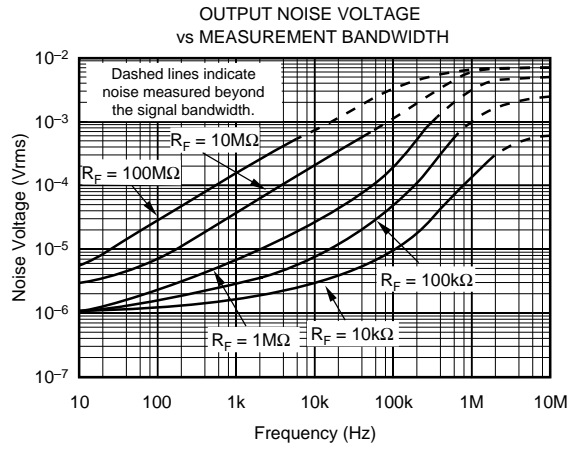
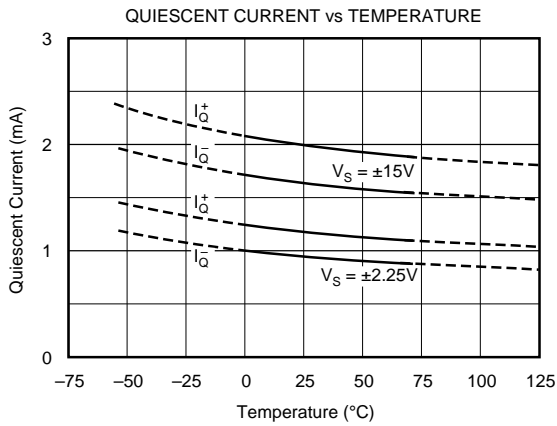
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $\lambda = 650\text{nm}$ , unless otherwise noted.

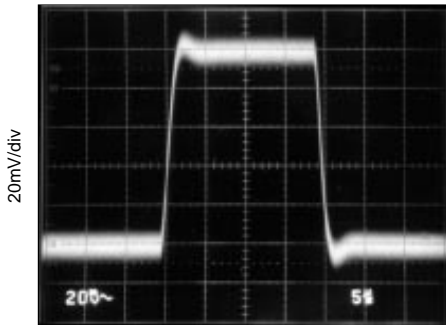


# TYPICAL PERFORMANCE CURVES (CONT)

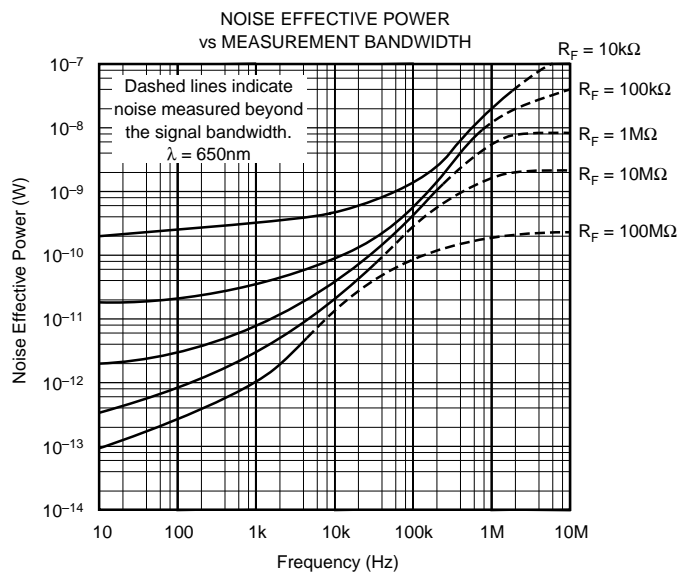
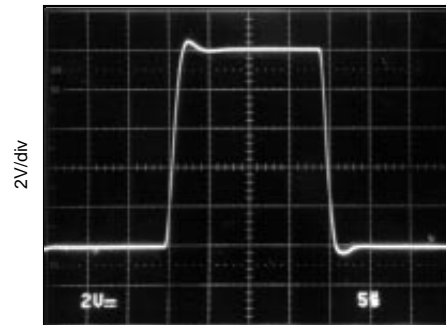
At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $\lambda = 650\text{nm}$ , unless otherwise noted.



SMALL-SIGNAL RESPONSE,  $R_F = 1\text{M}\Omega$   
Measurement BW = 1MHz



LARGE-SIGNAL RESPONSE,  $R_F = 1\text{M}\Omega$



# APPLICATIONS INFORMATION

Basic operation of the OPT210 is shown in Figure 1. Power supply bypass capacitors should be connected near the device pins as shown. Noise performance of the OPT210 can be degraded by the high frequency noise on the power supplies. Resistors in series with the power supply pins as shown can be used (optional) to help filter power supply noise

An external feedback resistor,  $R_F$ , is connected from  $-In$  to the  $V_O$  terminal as shown in Figure 1. Feedback resistors of  $1M\Omega$  or less require parallel capacitor,  $C_F$ . See the table of values in Figure 1.

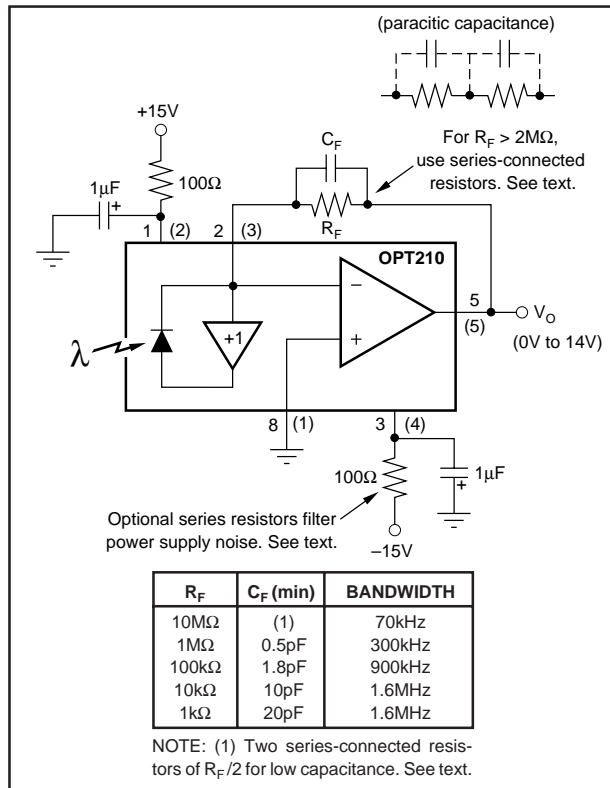


FIGURE 1. Basic Operation.

Bandwidth varies with feedback resistor value. To achieve widest bandwidth with resistors greater than  $1M\Omega$ , use care to minimize parasitic parallel capacitance. For widest bandwidth with resistors greater than  $2M\Omega$ , connect two resistors ( $R_F/2$ ) in series. Airwiring this interconnection provides lowest capacitance. Although the OPT210 is usable with feedback resistors of  $100M\Omega$  and higher, with  $R_F \geq 10M\Omega$  the model OPT211 will provide lower dc errors and reduced noise.

The OPT210's output voltage is the product of the photodiode current times the external feedback resistor,  $R_F$ . Photodiode current,  $I_D$ , is proportional to the radiant power or flux (in watts) falling on the photodiode. At a wavelength of 650nm (visible red) the photodiode Responsivity,  $R_F$ , is approximately  $0.45A/W$ . Responsivity at other wavelengths is shown in the typical performance curve "Responsivity vs Wavelength."

The typical performance curve "Output Voltage vs Radiant Power" shows the response throughout a wide range of radiant power and feedback resistor values. The response curve "Output Voltage vs Irradiance" is based on the photodiode area of  $5.23 \times 10^{-6} m^2$ .

## BOOTSTRAP BUFFER

The photodiode's anode is driven by an internal high speed voltage buffer shown in Figure 1. This variation on the classical transimpedance amplifier circuit reduces the effects of photodiode capacitance. The effective photodiode capacitance is reduced from approximately 550pF to 10pF with this bootstrap drive technique. This improves bandwidth and reduces noise.

The output voltage of the buffer is offset approximately 1.2V below the input. This reverse biases the photodiode for reduced capacitance.

## OP AMP

A special op amp design is used to achieve wide bandwidth. The op amp output voltage cannot swing lower than 0.5V below the non-inverting input voltage. Since photodiode current always produces a positive output voltage, this does not limit the required output swing.

The inverting input is designed for very low input bias current—approximately 15pA. The non-inverting input has much larger bias current—approximately  $300\mu A$  flows out of this terminal.

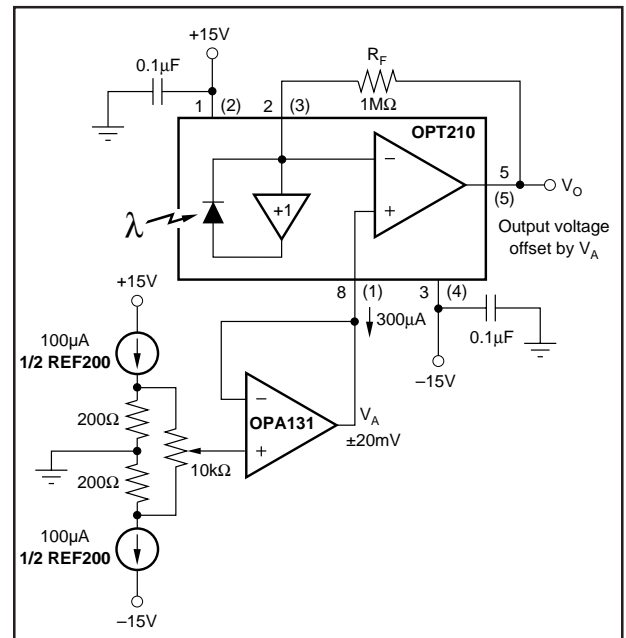


FIGURE 2. Adjustable Output Offset.

An offset voltage can be connected to the non-inverting input as shown in Figure 2. A voltage applied to the non-inverting input is summed at the output. Because the non-inverting input bias current is high (approximately  $300\mu A$ ), it should be driven by a low impedance such as the buffer-connected op amp shown.



The OPT210 can be connected to operate from a single power supply as shown in Figure 3. The non-inverting input bias current flows through a zener diode to provide a bias voltage. The output voltage is referenced to this bias point.

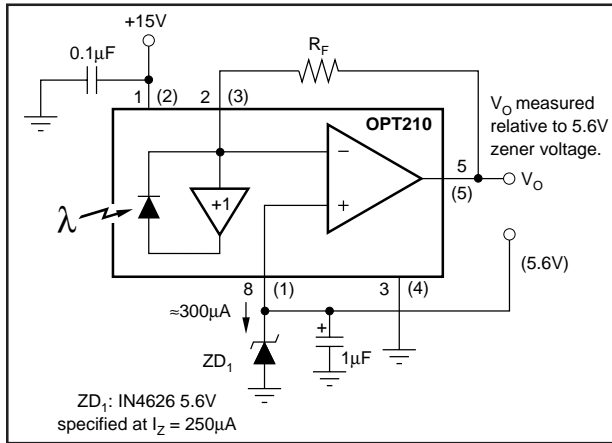


FIGURE 3. Single Power Supply Operation.

### DARK ERRORS

The dark errors in the specification table include all sources with  $R_F = 1M\Omega$ . The dominant error source is the input offset voltage of the op amp. Photodiode dark current is approximately 70pA and the combined input bias current of the op amp and buffer is approximately 30pA. Photodiode dark current and input bias current total approximately 100pA at 25°C and double for each 10°C above 25°C. At 70°C, the total error current is approximately 2nA. With  $R_F = 1M\Omega$ , this would produce a 2mV offset voltage in addition to the initial amplifier offset voltage (10mV max) at 25°C. The dark output voltage can be trimmed to zero with the optional circuit shown in Figure 2.

### LIGHT SOURCE POSITIONING

The OPT210 is tested with a light source that uniformly illuminates the full integrated circuit area, including the op amp. Although all IC amplifiers are light sensitive to some degree, the OPT210 op amp circuitry is designed to minimize this effect. Sensitive junctions are shielded with metal where possible. Furthermore, the photodiode area is very large compared to the op amp circuitry making these effects negligible.

If your light source is focused to a small area, be sure that it is properly aimed to fall on the photodiode. If a narrowly focused light source were to miss the photodiode and fall on the op amp circuitry, the OPT210 would not perform properly. The large photodiode area is clearly visible as a very dark area slightly offset from the center of the IC.

The incident angle of the light source also affects the apparent sensitivity in uniform irradiance. For small incident angles, the loss in sensitivity is due to the smaller effective light gathering area of the photodiode (proportional to the

cosine of the incident angle). At a greater incident angle, light is diffused by the side of the package. These effects are shown in the typical performance curve, "Response vs Incident Angle."

### LINEARITY PERFORMANCE

Photodiode current is very linear with radiant power throughout its range. Nonlinearity remains below approximately 0.01% up to 200µA. The anode buffer drive, however, is limited to approximately 200µA. This produces an abrupt limit to photodiode output current when radiant power reaches approximately 450µW.

Best linearity is achieved with the photodiode uniformly illuminated. A light source focused to a very small beam, illuminating only a small percentage of the photodiode area, may produce a higher nonlinearity.

### NOISE PERFORMANCE

Noise performance of the OPT210 is determined by the op amp characteristics in conjunction with the feedback components, photodiode capacitance, and buffer performance. The typical performance curve "Output Noise Voltage vs Measurement Bandwidth" shows how the noise varies with  $R_F$  and measured bandwidth (0.1Hz to the indicated frequency). The signal bandwidth of the OPT210 is indicated on the curves. Noise can be reduced by filtering the output with a cutoff frequency equal to the signal bandwidth.

Output noise increases in proportion to the square-root of the feedback resistance, while responsivity increases linearly with feedback resistance. So best signal-to-noise ratio is achieved with large feedback resistance. This comes with the trade-off of decreased bandwidth.

The noise performance of a photodetector is sometimes characterized by *Noise Effective Power* (NEP). This is the radiant power which would produce an output signal equal to the noise level. NEP has the units of radiant power (watts), or  $\text{Watts}/\sqrt{\text{Hz}}$  to convey spectral information about the noise. The typical performance curve "Output Noise Voltage vs Measurement Bandwidth" is also scaled for NEP on the right-hand side.