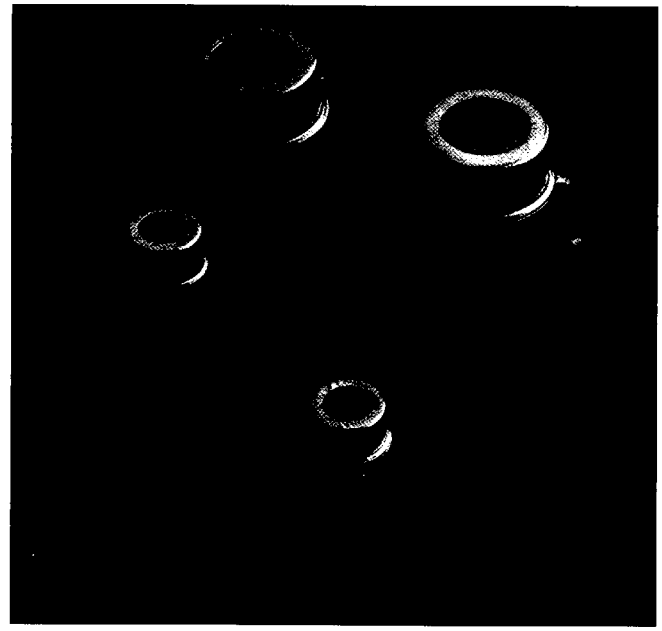
Large Area InGaAs Photodiodes



Features

- High responsivity at 1300, 1550, and 850 nm.
- Low dark current for high accuracy
- High shunt resistance for low noise
- Linear over wide range of input optical power
- 0.5, 1, 2, and 3 mm active diameters

Applications

- Optical power meters
- Optical fiber identifiers
- Optical attenuation test sets
- Near infrared spectroscopy
- Infrared rangefinders

Description

The EPITAXX series of large area Indium Gallium Arsenide (InGaAs) photodetectors consists of PIN diodes that have photosensitive areas with diameters of 500 µm, 1000 µm, 2000 µm, and 3000 µm. These photodiodes have high spectral responsivity in the near infrared range, between 800 and 1700 nanometers. They are designed with large active areas so they can be used for instrumentation, sensing and rangefinding applications.

These detectors feature high sensitivity to low level signals and spectral responsivity that is linear over a wide dynamic range of input optical power. In an unbiased mode, these large area photodiodes have high sensitivity because InGaAs exhibits higher shunt resistance than other near infrared detection materials. When reverse biased for greater bandwidth, their sensitivity stems from the diodes' low dark current. Since shunt resistance decreases and dark current increases with junction area, the smallest area ETX 500T has the highest sensitivity (lowest noise current density): at room temperature, 10fA/Hz$^{1/2}$ at 0V and 60fA/Hz$^{1/2}$ at -5V are typical. Highly linear spectral response results from the low series resistance of the large area photodiodes. For the ETX 3000T5, linearity is typically ±0.15dB to +7dBm.

EPITAXX large area detectors are recommended for near infrared instrumentation applications that require low photodiode noise. The ETX 500T and ETX 1000T are well suited for high speed, differential mode measurements. Such measurements are common in precision optical power meters, optical fiber identifiers, and optical loss test sets. The ETX 2000T5 and ETX 3000T5 are optimal for field instruments, as the diodes' large diameters simplify coupling incident radiation into their photosensitive areas. These instruments include attenuation sets and the above mentioned meters and identifiers. In addition, the high linearity of the ETX 2000T5 and ETX 3000T5 makes these detectors appropriate for measuring signals that vary over a wide dynamic range. Such signals are frequent in local area networks and in high fan-out systems.

The ETX 500T and ETX 1000T are available in a single grade. There are two grades of ETX 2000T5 and ETX 3000T5: the economical J Grade and the standard K Grade, which has a higher shunt resistance. The package for the ETX 500T and ETX 1000T is a hermetically sealed TO-46 can; the ETX 2000T5 and ETX 3000T5 are packaged in hermetically sealed TO-5 cans. All EPITAXX large area photodiodes are also available mounted on standard or custom ceramic subcarriers.

Specifications

MODEL	ETX 500T			ETX 1000T			ETX 2000T5			ETX 3000T5			Units
Conditions (unless noted)	25°C, V_R = 5V			25°C, V_R = 5V			25°C, V_R = 0V			25°C, V_R = 0V			
Parameter	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Active Diameter		0.5			1.0			2.0			3.0		mm
Responsivity @ 850 nm	0.10	0.20		0.10	0.20		0.10	0.20		0.10	0.20		A/W
Responsivity @ 1300 nm	0.80	0.90		0.80	0.90		0.80	0.90		0.80	0.90		A/W
Responsivity @ 1550 nm		0.95			0.95			0.95			0.95		A/W
Dark Current[1]		12	100		50	400		900			2000		nA
Shunt Resistance[2]													
J (Economy)	5.0	250		2.0	50		0.8	3.0		0.1	0.4		MΩ
K (Standard)							10	25		1.0	10.0		MΩ
Linearity[3]		± 0.15			± 0.15			± 0.15			± 0.15		dB
Total Capacitance[4]		35	50		100	150		400	600		800	1300	pF
Bandwidth[5]		140			35			5.3			2.6		MHz

Notes: 1) V_R = 1V for ETX 2000T5 and ETX 3000T5
2) V_R = 10 mV
3) For ETX 500T and ETX 1000T, to +9 dBm; for ETX 2000T5 and ETX 3000T5, to +7 dBm
4) For ETX 500T and ETX 1000T, V_R = 0 V
5) -3dB point into a 50Ω load

Maximum Ratings

MODEL	ETX 500T	ETX 1000T	ETX 2000T5	ETX 3000T5	Units
Reverse Voltage	20	20	2	2	V
Reverse Current[A]	10	10	10	10	mA
Forward Current[B]	10	10	10	10	mA
Power Dissipation	100	100	50	50	mW
Operating Temperature	-40 +85	-40 +85	-40 +85	-40 +85	°C
Storage Temperature	-40 +85	-40 +85	-40 +85	-40 +85	°C

Notes: A) Under reverse bias, current at which device may be damaged.
B) Under forward bias, current at which device may be damaged.

Figure 1

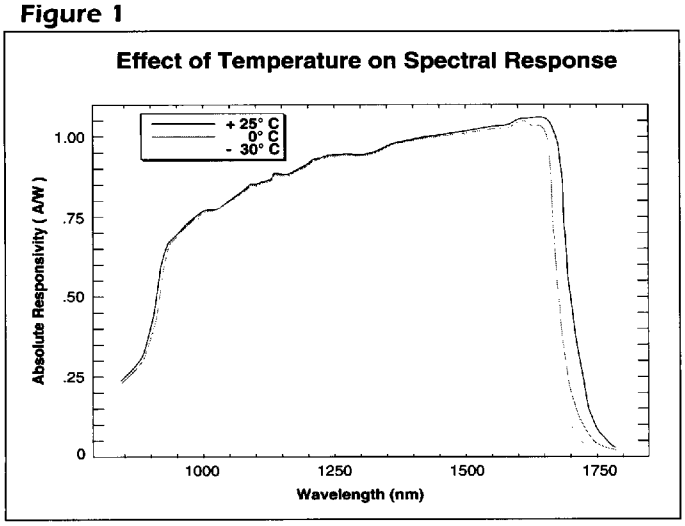


Figure 2

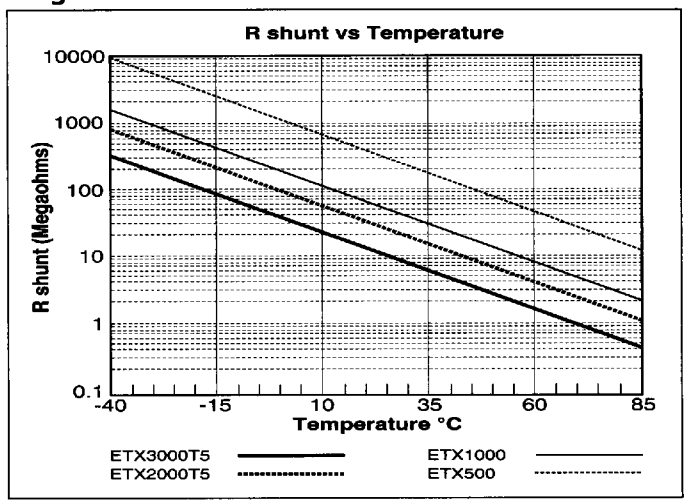


Figure 3

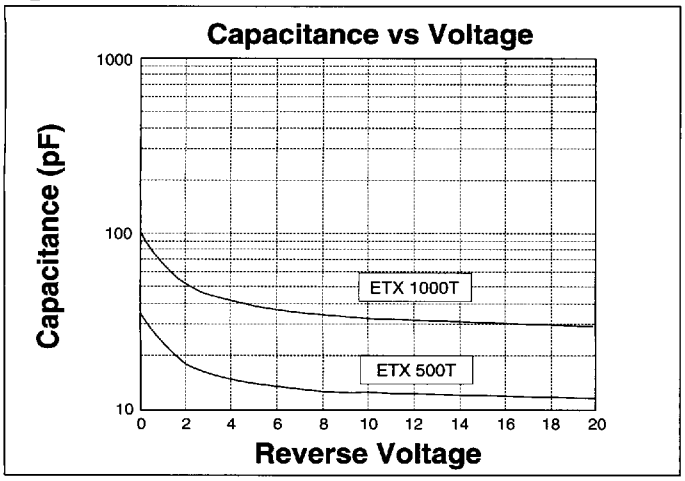


Figure 4

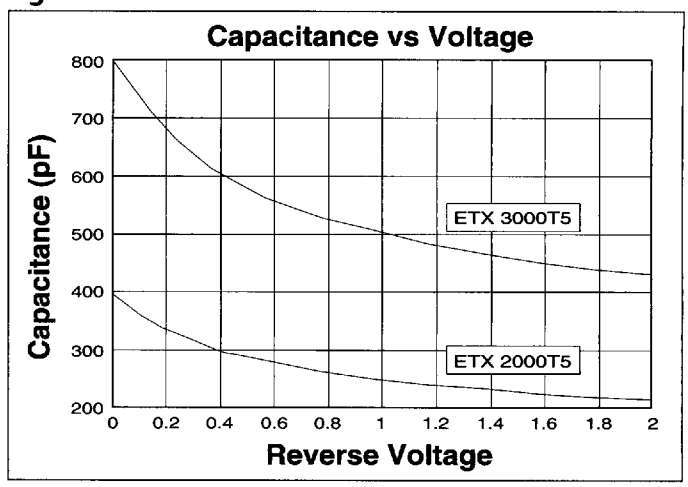


Figure 5

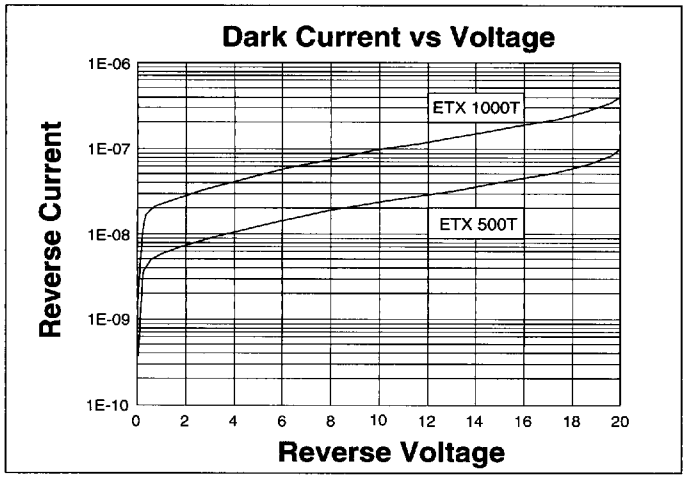


Figure 6

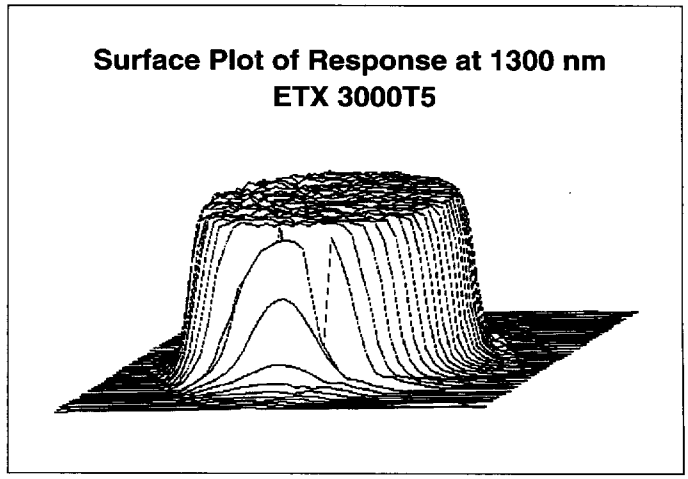
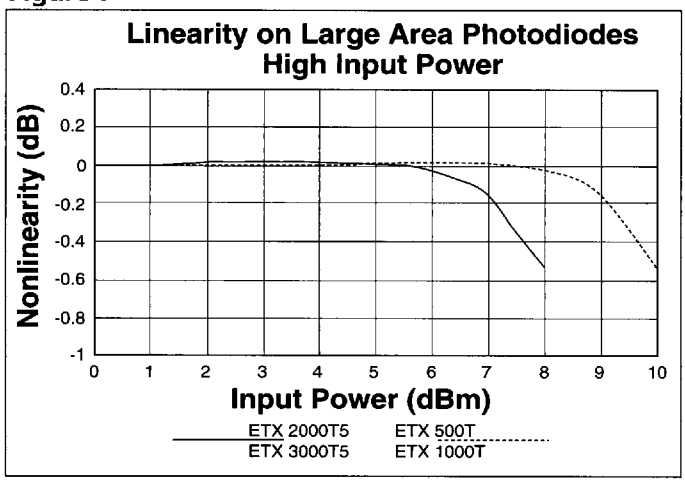


Figure 7



Large Area Detectors

Enlarging the area of a photodetector increases the amount of light the detector can collect. In general, a large area photodiode decreases the cost of optical components required for coupling light into a detector. Savings occur since a wider diameter permits relaxation of tolerances for focusing the incident beam or for positioning the detector.

Spectral Responsivity

Any variation in spectral responsivity degrades the performance of photodetection instrumentation. Sources of variation include deviations across the surface of the detector and changes in magnitude as a function of temperature. EPITAXX large area InGaAs photodetectors exhibit highly uniform responsivity across their surfaces: at 1300 nm, uniformity is typically within ±2%. In addition, temperature minimally affects the magnitude of responsivity (See Figure 1). As shown in the figure, the cutoff wavelength – the upper wavelength at which detector response is 10% of the peak value – rises 0.9 nanometers for every degree Celcius increase in temperature. Below the cutoff, temperature has virtually no effect on the magnitude of wavelength response, as shown in the figure by the relatively flat response of the InGaAs detector.

Sensitivity

EPITAXX InGaAs photodiodes are extremely sensitive to low level signals in the near infrared (800 to 1700 nm) range. This sensitivity derives from EPITAXX device design and processing techniques that yield high shunt resistance, low drift in noise with temperature, and low dark current.

High shunt resistance is necessary when a detector is operated in a zero bias or photovoltaic mode. In these cases, the dominant source of noise from a photodiode is thermal, or Johnson, noise. Equation 1 presents the thermal noise current per unit bandwidth. As Equation 1 shows, maximizing shunt resistance decreases thermal noise. Since EPITAXX designs and manufactures its large area InGaAs photodiodes specifically for high shunt resistance, they exhibit low thermal noise. As an example, the shunt resistance of the 2 mm diameter ETX 2000T5 at room temperature is typically 25 MOhms, so thermal noise current per unit bandwidth is just 30 fA / $Hz^{1/2}$.

In addition, since its shunt resistance is highly stable with temperature, an InGaAs diode has low drift in thermal noise. Shunt resistance for InGaAs rises 70% with every 10°C fall in temperature. Low drift, coupled with high shunt resistance, gives these photodiodes high sensitivity to low level signals when operated with zero bias.

Equation 1: $I_{Th}^{*2} = 4kT/R_{sh}$

where
- I_{Th}^{*} is the thermal noise current per root Hertz
- k is Boltzmann's constant
- T is temperature (Kelvin)
- R_{sh} is the shunt resistance of the diode

When the photodiode is operated under reverse bias, the low dark current of InGaAs becomes advantageous. Under this condition, dark current is important because shot noise becomes the dominant source of noise. Equation 2 shows the formula for the shot noise current density of a photodiode.

Equation 2: $I_{SH}^{*2} = 2q\,|\,I_{ph}\,| + 2q\,|\,I_D|$

where
- I_{SH}^{*} is the shot noise current per root Hertz
- q is the unit of electronic charge
- I_{ph} is the photo-generated current
- I_D is the photodiode's dark current

For instance, the shot noise of an unilluminated 500 µm InGaAs photodiode with a reverse bias of 5V and at room temperature stems just from the dark current. Using the dark current's typical value of 12 nA, we compute that the noise current density is 62 $fA/Hz^{1/2}$.

Linearity

The linear range of a photodetector is the range of optical input power over which the spectral responsivity of the detector stays within a defined tolerance. For a non-biased diode, thermal noise establishes the lower limit of the linear range. The diode's turn-on voltage sets the upper limit. The linearity of an unbiased photodiode, connected across the inputs of a transimpedance amplifier, degrades when the product of the diode's output current and series resistance reaches the turn-on voltage. At this voltage, the diode generates electronic current as well as photocurrent. The electronic current flows in the forward direction, opposite to the direction of the photocurrent. The difference in direction makes the diode's total output current less than the product of the input optical power and the spectral responsivity. Any further increase in optical power incident on the photodiode generates just enough electronic current to cancel the incremental photocurrent and to keep the potential across the diode at its turn-on voltage. The cancelling effect of the electronic current degrades the linearity of the photodiode at high input optical power.

The relationship among turn-on voltage, spectral responsivity, and series resistance implies that the detector manufacturer can increase the upper limit of the linear range by lowering the diode's series resistance. EPITAXX has designed its large area photodetectors accordingly, as a typical series resistance is 25 Ω.

The user, as well, can increase the upper limit of the linear range by reverse biasing the photodiode. The reverse bias adds an offset to the diode voltage so that reaching the turn-on voltage now requires an even stronger photocurrent. A tradeoff is incurred, however, as increasing the reverse bias also increases the flow of dark current. The larger dark current degrades resolution at low levels and so decreases linearity at low optical input power.

Response Time

A photodiode has a response time, or rise time and fall time, that is expressed in the following form:

$$t_r = 2.2 * (R_{series} + R_{load}) * C$$

In the equation, R_{series}, which comes from the photodiode, is typically 25Ω for an InGaAs photodiode. **C** is the total capacitance of the packaged detector. The following table shows typical values of of rise times for 500 to 3000 µm diameter InGaAs photodiodes into a 50Ω load.

Active Diameter µm	Reverse Bias V	Capacitance pF	Rise / Fall Time ns
500 µm	5	15	2.5
1000 µm	5	40	6.6
2000 µm	1	250	41
2000 µm	0	400	66
3000 µm	1	500	82
3000 µm	0	800	132

Reverse biasing, which increases the upper limit of the linear range, also decreases response time. The detector's bandwidth rises because the applied voltage increases the depletion layer thickness so the capacitance falls. As mentioned above, however, reverse biasing also degrades resolution by increasing shot noise current.

Quality and Reliability

EPITAXX maintains a strict quality control program throughout the design and manufacturing process of its photodetectors. All products are evaluated against MIL-STD 883C, Bellcore, or custom specifications. EPITAXX purges each large area photodiode at 125°C and -20V for 18 hours. Long-term lifetesting has indicated an expected lifetime of at least 10^7 hours for the ETX 2000T5 and ETX 3000T5 and at least 10^{12} hours for the ETX 500T and ETX 1000T. Call EPITAXX to learn details of specific qualification tests performed on the large area InGaAs photodiode series.

Options

For increased detectivity, EPITAXX offers 2 and 3mm detectors in custom, cooled packages. One option is to mount a detector on a two stage thermoelectric cooler (ETX 2000TE and ETX 3000TE). These detectors are assembled on a TO-37 header with a hermetically sealed, windowed cap. A second option is to install the detector inside a liquid nitrogen dewar, which enables the user to operate the photodiode at 77°K. EPITAXX also manufactures larger diameter InGaAs photodetectors on a custom basis. Call EPITAXX for specifications and additional information.

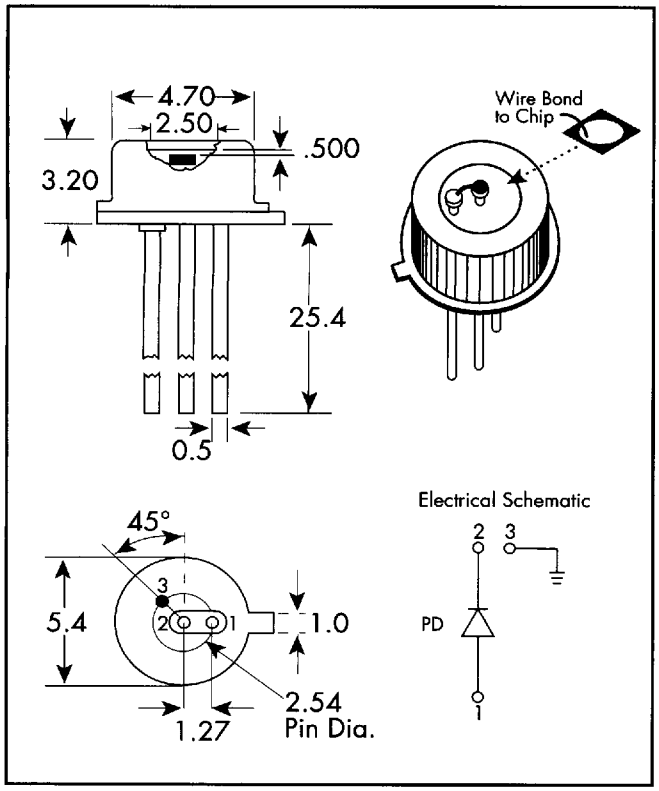
Precautions for Use

99% pure, reagent grade isopropanol should be used to clean glass windows.

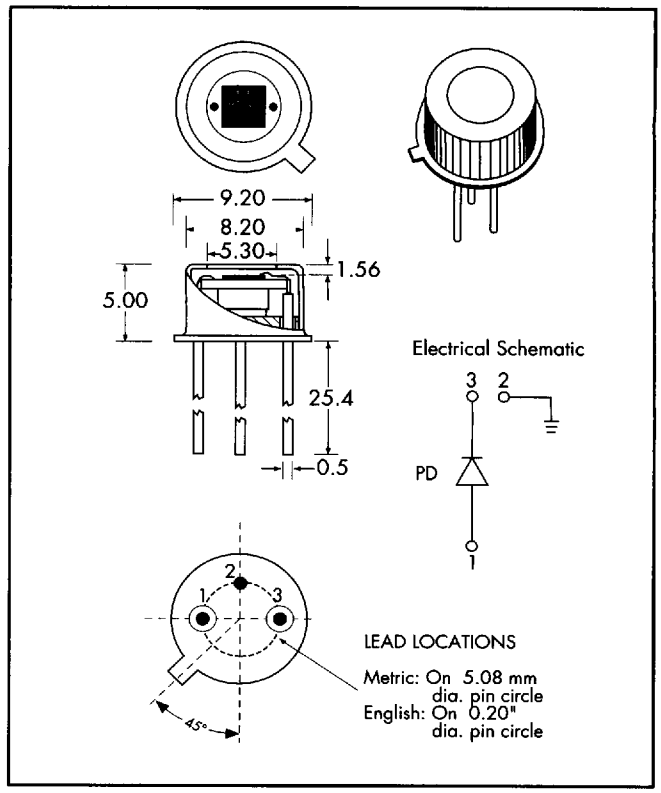
ESD Protection is Imperative. Use of grounding straps, anti-static mats, and other standard ESD protective equipment is recommended when handling or testing any InGaAs PIN or any other junction photodiode.

Mechanical Dimensions

ETX 500T, ETX 1000T
All dimensions in mm



ETX 2000T5, ETX 3000T5
All dimensions in mm



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