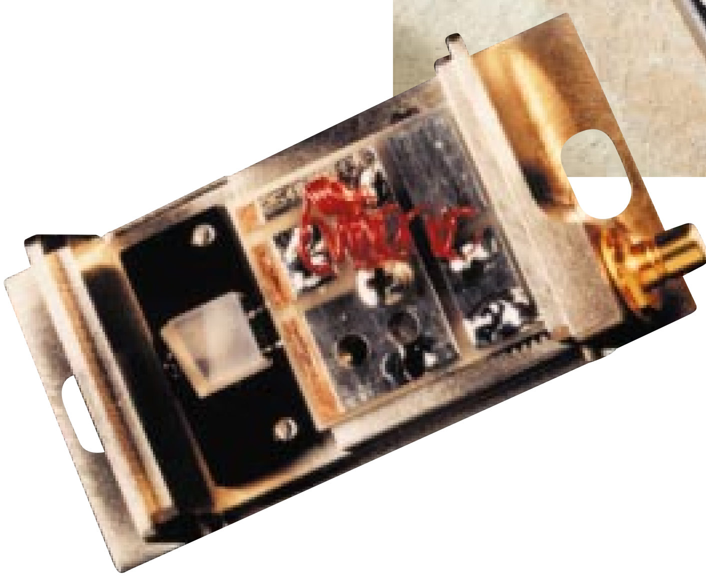
Acousto-Optic

application note – modulator model 3000 series



Crystal Technology's (CTI) acoustic-optic modulators of the Model 3000 Series provide a reliable, economical means for amplitude modulation of laser light. When coupled with a companion driver module from the CTI Model 1000 Series, they provide an easy-to-use combination for a wide variety of applications.

This application note is intended to acquaint the user with a few precautions which should be observed in order to obtain optimum device performance quickly and conveniently.

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BASIC THEORY

As shown in Figure 1 (a) and (b), this series of devices operate by Bragg diffraction of an incident light beam from a moving acoustic wavefront. The intensity of light diffracted into the output beam is dependent on the power of the acoustic beam which is in turn dependent on the modulation signal input to the driver. The modulation signal to optical output transfer function is monotonic but non-linear. This is unimportant for digital modulation. Information concerning analog-modulation applications can be obtained from the factory.

For those interested in a general technical analysis, Reference 1 is recommended.

ALIGNMENT

For proper modulator operation, the optical beam and sound beam must interact with the proper relationship. This requires that several conditions be met simultaneously.

First, the acoustic beam (modulator housing) must be slightly rotated off perpendicular to the optical beam so that the Bragg angle condition is met as shown in Figure 1. This can be accomplished either side of perpendicular with only a slight difference in performance as described later. The proper Bragg angle for each device is tabulated on the individual data sheets.

Second, the modulator must be translated vertically so the optical beam passes through the acoustic beam. This adjustment is more critical for the high-performance (wideband) units which have acoustic beams of very small height. In fact, a slight design compromise is made in these units to avoid having this adjustment be excessively critical. An estimate of the required precision and stability of this adjustment is 25% of the "active aperture", as tabulated on the data sheets, e.g. ~.001" for Model 3350.

Third, the focusing lens for the incident optical beam must be positioned longitudinally so that the optical beam focus (beam waist) is located at the acoustic column. If the beam waist location is determined in air before the modulator is introduced, then

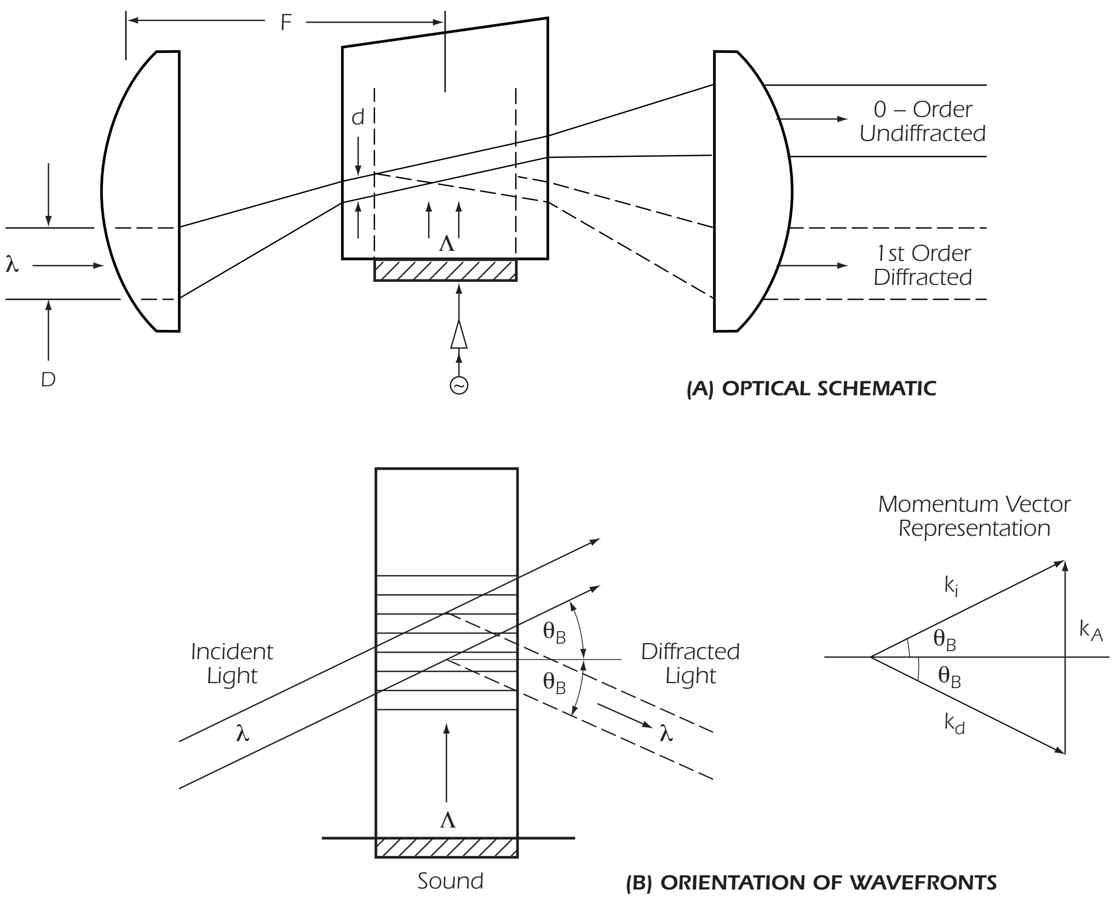

FIGURE 1. MODULATOR CONFIGURATION

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the lens should be moved away from the modulator location to account for the increased optical path length inside the modulator crystal. This increment is ~6.2 mm for Models 3080 and 3110, and ~1.7 mm for Model 3200.

To obtain the proper optical beam waist diameter (d) stipulated in the device data sheets requires the following relationship:

$$d = \frac{1.27F\lambda}{D}$$

Where: D = Input laser beam, diameter ($1/e^2$ intensity points)
F = Focal length of input focusing lens
λ = Light wavelength

A single-element, plano-convex lens, oriented as shown, will give satisfactory results.

Finally, in the case of the Model 3350, the optical beam should be positioned close to the acoustic transducer to minimize effects of acoustic attenuation and acoustic beam spreading from diffraction.

Figure 2 is included as an aid in obtaining correct adjustments. The images are shown as outputs without the recollimating optics. However, they should not be viewed directly, but as reflections from a diffuse surface such as a 3 x 5-inch file card. The zero and first orders are point for point complementary (sum = 1). The missing area in the zero order beam corresponds to light diffracted into the first order. In practice, the zero order may be easier to interpret, particularly if the laser power can be reduced to avoid eye saturation.

It should be noted that there is a slight variation in diffraction efficiency with the polarization of the incident optical beam. Polarization perpendicular to the mounting surface of the modulator is usually preferred in TeO_2 devices.

Any need to correct variations in input laser power can be met by a new addition to the Series 1000 driver family which provides for feedback correction from a beam-sampling optical detector.

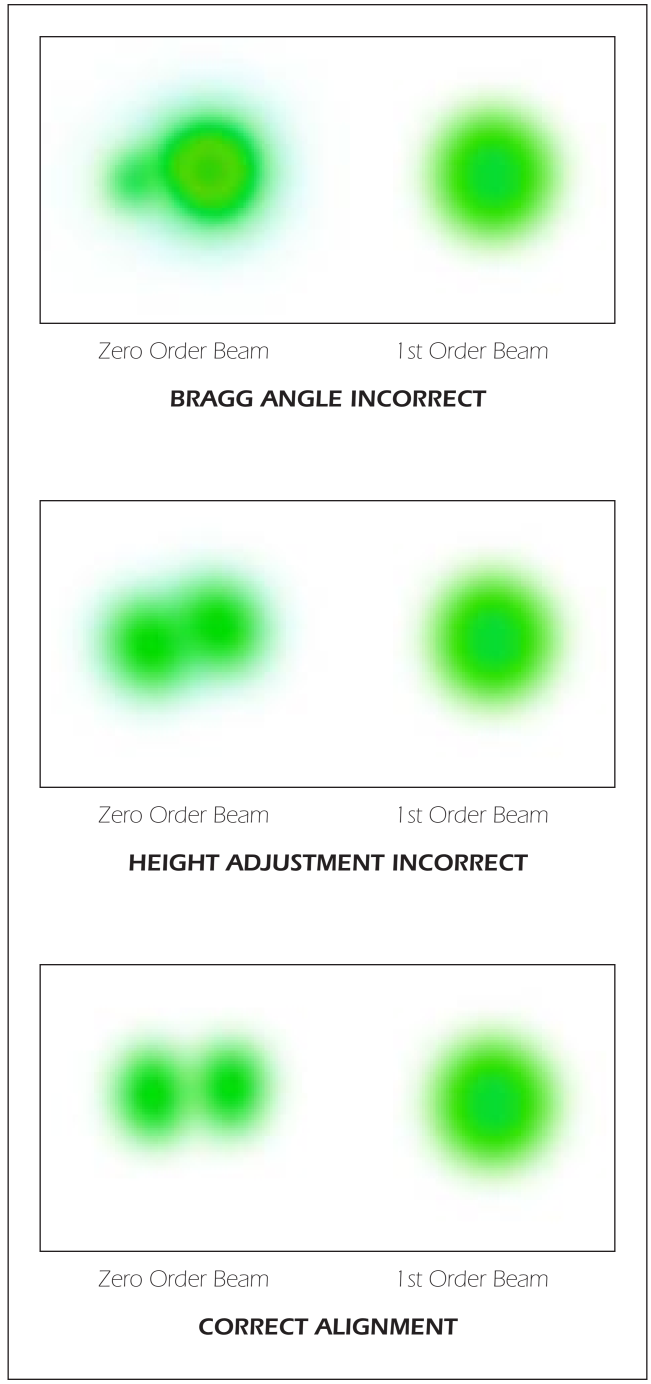

FIGURE 2. ALIGNMENT BEAM PATTERNS

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MODULATION BANDWIDTH/TRANSIENT RESPONSE

Generally speaking, the most important parameter of an AO modulator is the transient response of the output light beam. Referring to Figure 1, it is seen that this is dependent on the time required for an acoustic pulse packet to transmit across the optical beam. In order to improve response time, the optical beam is focused to a small width in the direction of acoustic propagation.

In practice, rise time/bandwidth, diffraction efficiency and required RF drive power are closely interrelated. Modulator performance can be optimized over a fairly narrow range of parameter variation. Consequently, CTI offers a family of devices. Attempts to operate a given device outside the recommended range of parameters will inevitably result in degraded performance.

For example, focusing the optical beam to a smaller spot size than recommended in an effort to decrease rise time will result in a rapid loss of diffraction efficiency without the desired improvement in response. A second, potentially serious result, is an increase in the elliptical eccentricity of the output beam shape. This in turn degrades the diffraction limited spot which can be formed subsequently. Conversely, failure to focus the optical beam to a sufficiently small diameter will also result in reduced diffraction efficiency, since the acoustic beam fails to intercept all of the optical beam.

Under optimum conditions, the modulator rise time (T_r) is (as given in Reference 1):

$$T_r = \frac{0.66d}{V} \sim T_f$$

Where: d = Optical beam waist diameter
V = Acoustic wave velocity
T_f = Fall time

For the common case of digital square-wave modulation (50% duty cycle) at low frequency, the signal excursion is from 0 to full diffraction with $T_r = T_f$. As the carrier frequency is increased, the flat portions of the signal output decrease. Gradually the leading and trailing edges merge and 100% modulation is no longer achieved. The signal content is essentially the fundamental of the square-wave drive which is down to 50% modulation (-3 dB) at:

$$f_m \sim \frac{1}{2T_r}$$

If a particular application permits operation at less than 100% signal modulation, a relationship from Reference 2 can be utilized:

$$f_m = \frac{0.29\sqrt{B}}{T_r}$$

Where: f_m = Signal frequency (modulation)
T_r = Device rise time
B = Attenuation in dB which that modulation will suffer

RISE TIME ASYMMETRY

As mentioned above, the Bragg condition can be achieved with either of two incident optical beam orientations. This is shown in more detail in Figure 3. By convention, a "doppler" upshifted (increased optical frequency) diffracted beam is termed a (+1) diffracted order, and a downshifted beam, a (-1) diffracted order.

As an acoustic pulse packet enters and exits the optical beam, dynamic conditions are slightly different, resulting in a fall time longer than a rise time for the (+1) order. The situation is reversed for the (-1) order, in which case the rise time exceeds the fall time.

This effect is normal and becomes discernible as device bandwidth is increased. In the extreme, the steeper edge may be accompanied by some overshoot, even when driven by an ideal RF waveform. Interested users may gain further insight into this effect from Reference 3.

DEVICE DAMAGE

The factory should be consulted if operation is anticipated at optical power densities incident on the crystal face in excess of 25 kw/cm^2.

When operated with the proper companion driver unit, the modulator cannot be harmed by any combination of driver control settings. Otherwise, the power delivered from a well matched source to the modulator must not exceed the capability of the CTI Series 1000 companion driver as indicated on the data sheet. Since the transducer thermodynamics are somewhat complex, this restriction should be observed regardless of the pulse-modulation duty cycle.

Reasonable care should be observed in the mechanical handling of these devices. The shock and vibration associated with mechanical modification must strictly be avoided.

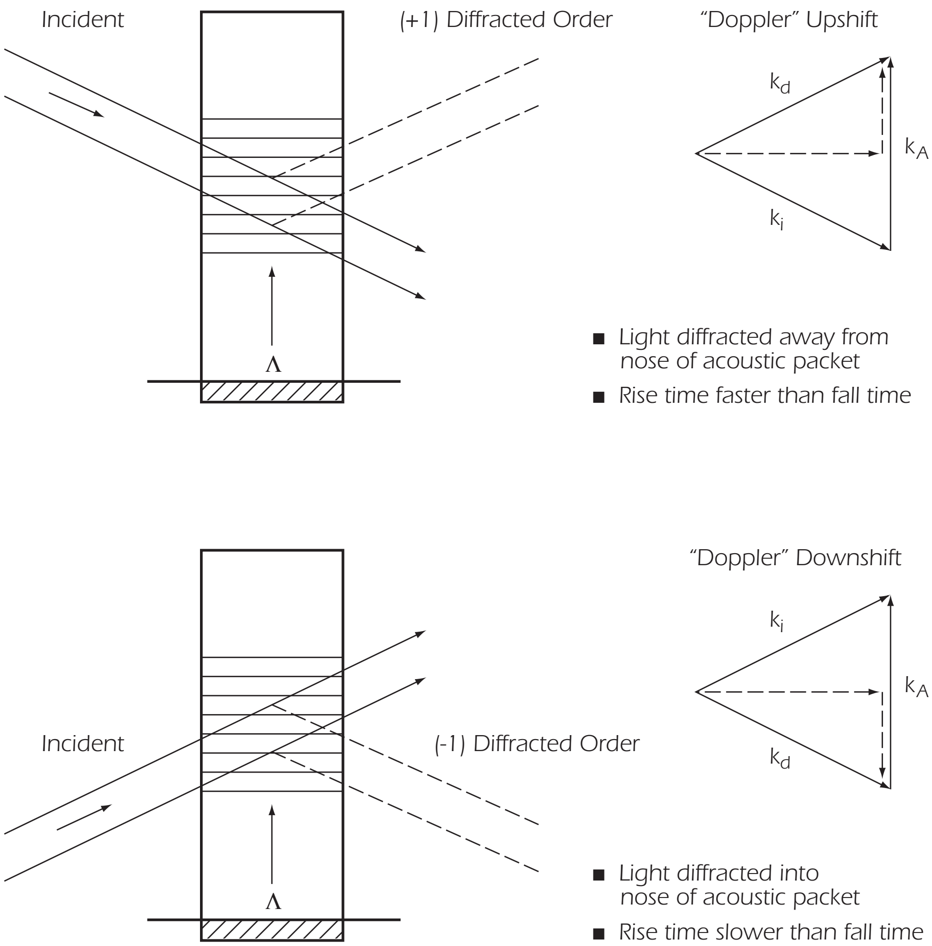


FIGURE 3. RISE TIME ASYMMETRY

REFERENCES

[1] D. Mayden , "Acousto-optical Pulse Modulators", Journal of Quantum Electronics, vol. QE-6, no. 1, pp. 15-24 (January 1970)

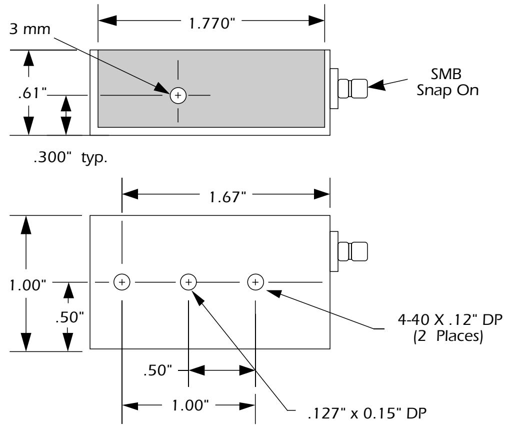
[2] Young and Yao, "Design Consideration for Acousto-optic Devices, " Proceedings of IEEE, vol. 69, no. 1, pp. 54-64 (January 1981)

[3] Richard V. Johnson, " Temporal Response of the Acousto-optic Modulator in the High Scattering Efficiency Regime", Applied Optics, vol. 18, pp. 903-907 (March 1979)

Acousto-Optic Modulators

Model #	Part #	l (nm)	Material	Center Freq	Min Rise Time (ns)	Max Mod BW (MHz)	Active Acoustic Aperture (L x H)	Package	Connector Type
3200-125	97-01684-01	325-365	Fused Silica	200	10.0	50.0	3.0 x 0.40	Style 2	SMB
3110-121	97-01638-01	442-488	TeO_2	110	18.2	27.5	3.0 x 0.60	Style 2	SMB
3200-120	99-48146-10	442-488	TeO_2	200	10.0	50.0	3.0 x 0.45	Style 2	SMB
3200-130	99-20022-01	442-488	TeO_2	200	10.0	50.0	3.0 x 0.40	Style 3	SMA
3200-141	99-48146-13	442-488	TeO_2	200	10.0	50.0	3.0 x 0.45	Style 4	SMA
3224-120	97-20010-01	442-488	TeO_2	224	8.9	56.0	3.0 x 0.45	Style 2	SMB
3225-120	97-20122-01	442-488	TeO_2	225	8.9	56.3	3.0 x 0.60	Style 2	SMB
3350-120	97-02089-01	488-532	TeO_2	350	5.7	87.5	2.0 x 0.10	Style 2	SMB
3080-110	99-48201-10	442-633	TeO_2	80	25.0	20.0	3.0 x 1.00	Style 1	SMB
3080-120	99-48201-11	442-633	TeO_2	80	25.0	20.0	3.0 x 1.00	Style 2	SMB
3080-125	97-01598-01	442-633	TeO_2	80	25.0	20.0	3.0 x 2.00	Style 2	SMB
3080-151	99-01000-01	442-633	TeO_2	80	25.0	20.0	2.0 x 2.00	Style 5	BNC
3110-110	99-48012-10	442-633	TeO_2	110	18.2	27.5	3.0 x 0.60	Style 1	SMB
3110-120	99-20068-01	442-633	TeO_2	110	18.2	27.5	3.0 x 0.60	Style 2	SMB
3110-140	97-00811-01	442-633	TeO_2	110	18.2	27.5	3.0 x 0.60	Style 4	SMA
3200-115	97-01621-01	515-633	TeO_2	200	10.0	50.0	3.0 x 0.40	Style 1	SMB
3200-121	99-48146-11	515-633	TeO_2	200	10.0	50.0	3.0 x 0.32	Style 2	SMB
3200-144	97-01407-02	515-633	TeO_2	200	10.0	50.0	3.0 x 0.32	Style 4	SMA
3080-122	97-01280-01	780-850	TeO_2	80	25.0	20.0	3.0 x 1.00	Style 2	SMB
3200-124	97-01544-01	780-850	TeO_2	200	10.0	50.0	3.0 x 0.32	Style 2	SMB
3080-123	97-01741-01	1047-1060	TeO_2	80	25.0	20.0	3.0 x 1.00	Style 2	SMB
3110-125	97-01672-03	1047-1060	TeO_2	110	18.2	27.5	3.0 x 1.25	Style 2	SMB
3125-120	97-01711-01	1047-1060	TeO_2	125	16.0	31.3	3.0 x 0.20	Style 2	SMB
3180-110	97-02159-03	1047-1060	TeO_2	180	11.0	45.0	3.0 x 0.10	Style1	SMB
3200-1113	97-02029-05	1047-1060	TeO_2	200	10.0	50.0	3.0 x 0.10	Style 1	SMB
3165-1	97-01287-02	1300-1550	TeO_2	165	12.1	41.3	3.0 x 0.60	Style 1	SMB

Acousto-Optic Modulators



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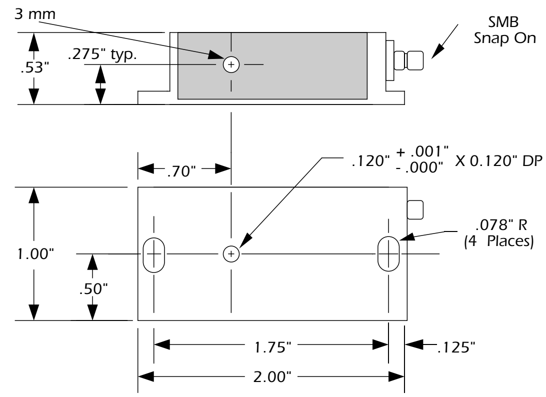

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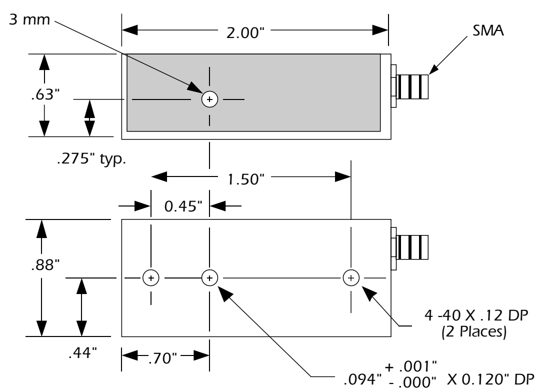

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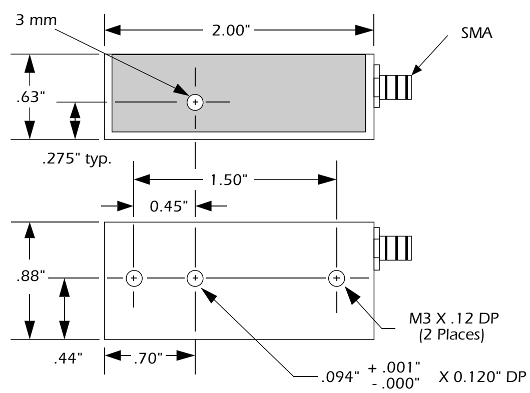

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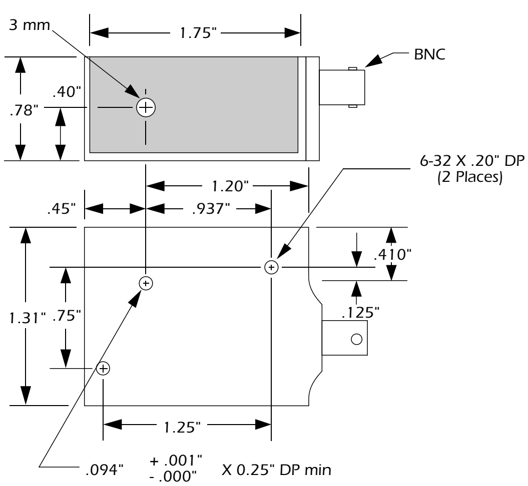

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