ELTEC INSTRUMENTS, INC.

PYROELECTRIC DETECTORS WITHOUT INTEGRAL ELECTRONICS:

NOTES ON SPECIFICATIONS AND TESTING (especially laser detectors)

An Eltec pyroelectric detector is essentially a thin wafer of lithium tantalate with electrodes on both faces. A change in optical radiation incident upon this wafer produces a temperature change with consequent change in the charge collected on the electrodes.

Since lithium tantalate is a dielectric material (insulation resistance greater than 1X10E13 ohms), this electroded wafer can be regarded as a low-loss "active" capacitor. The difference between the charge on the electrodes before and after the heating (or cooling) of the wafer is the detector signal. Since the charge is changing in time, we can speak of the current signal.

The radiation source (laser, blackbody, moving truck) is sending a stream of photons to the wafer, and the wafer, by virtue of its temperature and emissivity is "loosing" photons to the external world at the same time. There is a random fluctuation in the rate of photon arrival to- and photon emission from- the wafer...which produce slight thermal fluctuations in the wafer with corresponding changes in the output current. This mean square fluctuation is a limiting performance parameter for all thermal detectors.

With a 1 Hz bandwidth and the detector in a shielded, isothermal environment, the theoretical specific detectivity (D*) of such a detector is above 1X10E10 cm Hz(E1/2)/W. But all real pyroelectric detectors have a D* substantially below that value. Since the "noise" produced by the photon randomness is below the measured performance of today's finest detectors, this specific noise is not measurable, cannot be specified, and is only a minor component (at worst) of the total detector noise installed.

Since the wafer is a capacitor it has a dielectric constant (approximately 45) and a dielectric dissipation factor (loss tangent) of about 0.001 at 1 GHz. Viewing the wafer as a voltage generator, the detector is equivalent to a voltage source in series with both the wafer capacitance and insulation resistance in parallel. At high frequencies, the direct dependency of the conductance to the frequency and loss tangent allow conductance to increase which in turn increases the voltage noise. This is seldom a problem.

So as regards the "noise" of a detector that is simply an electroded wafer in a can with leads, there is no noise produced other than that produced due to the randomness of the photon exchange and the electrical limitations of the wafer considered simply as a specific capacitor.

At Eltec we make many thousands of detectors per month. Most of these have 1 or 2 lithium tantalate sensing elements, a high value, low noise load resistor, and very low noise JFET (basically, sensing elements in a source follower configuration). A standard, periodic QA Test involves taking a detector and making a noise test. The detector is then opened, the sensing element(s) removed and replaced with equivalent chip capacitors. Noise is measured again. Result: The noise (within the limits of error of the test instruments) is the same. Note that we are using good components, all in close proximity so as to minimize shunt capacitance, with connections made either with gold wire and/or precious-metal epoxy. Thus the real noise that we are measuring is simply the noise of the electronics attached to the sensing element (wafer). The noise of the wafer itself is orders of magnitude below that of whatever electronics are connected to the wafer. THEREFORE, ELTEC DOES NOT MAKE A NOISE SPECIFICATION FOR DETECTORS THAT CONTAIN SENSING ELEMENT(S) BUT NO INTERNAL ELECTRONICS.

RESPONSIVITY: CURRENT VS. VOLTAGE

If 2 metal plates of the same metal and top surface area--but with different thicknesses--were placed in sunlight, the temperature of the thin plate would rise faster than that of the thick plate (assuming no conductive or convective heat losses) because the energy in the thin plate couldn't diffuse as fast because it had less thermal mass. Pyroelectric detectors are somewhat like the metal plates: The thinner the crystal, the greater the charge generated for a given optical power input. With 2 crystals of equal thinness but different areas, as long as both crystals receive the same amount of optical power, the same amount of charge will be generated.

The change in charge per change in time is current (I), and is area independent. Whereas regarding the voltage developed across the electrodes, area beqomes capacitance and the charge has to "fill" the capacitor to get a voltage level. So in discussing voltage sensitivity, the capacitance must be taken into account. Moreover, involving capacitance mandates a consideration of the frequency (modulation rate, chopping rate, or pulse rate) to arrive at a number for the voltage sensitivity.

However, if you know the Current Responsivity and the Capacitance, you can obtain the Voltage Responsivity at a frequency of interest from the simple formula (see Eltecdata #100, page 100-3 & 100-4):

$$\text{Voltage Responsivity} = \frac{\text{(current responsivity)}}{(2)\text{x}(\text{pi})\text{x}(\text{frequency})\text{x}(\text{capacitance})}$$

Thus for Eltec, as a detector manufacturer supplying detectors that will be used in a wide, wide variety of modulation rates, the logical procedure is to measure Current Responsivity (at one frequency) and Capacitance. The user can then easily determine Voltage Responsivity. And Noise, as previously stated, is determined by the user's choice of circuity, components, lead-lenghts between components, and EMI/RFI shielding.

ELTEC INSTRUMENTS TEST PROCEDURE FOR DETECTORS INCORPORATING NO INTEGRAL ELECTRONICS:

Since there are no standard testing procedures for pyroelectric detectors, Eltec has established the following, comprising a capacitance test and a sensitivity test.

A. CAPACITANCE.

First, we insert the detector in a special test socket. The socket is manufactured by Robinson-Nugent and is their part #TS-5174. The sockets are especially useful in detector testing because there are, in effect, conical entrances to each pin connection so the socket also acts as a pin straightener. The pin connects are hollow so that the detector can be fully inserted without clipping the leads (detectors with clipped or soldered leads cannot be returned to Eltec).

For the capacitance test we use a General Radio (Gen Rad) RLC Digibridge #1657. In the picofarad range of capacitance of most pyroelectric detectors, a 1,000 Hz signal functions as the test input. Many other capacitance testers use a 1,000 Hz test voltage and will yield similar results.

The measured value is compared to the particular product specification. For example, the acceptable range of capacitance for Eltec Model 420 laser detectors is 29.4 to 44.1 picofarads.

B. DETECTOR CURRENT SENSITIVITY.

In the Eltec standard sensitivity test, the signal from the top electrode of the detector is fed to the inverting input of the LF355 operational amplifier and the bottom electrode connection is connected to the positive input and driven to ground. A feedback resistor of 1 X 10E10 ohms is connected from the inverting input to the amplifier output. This is termed "current mode" operation with the feedback resistor controlling the gain. (See attached schematic.) (Note that high megohm resistors are available from Eltec.)

The output (volts) = (1X10E10)x(current generated from detector)

Thus a 1 volt output from the amplifier corresponds to 100 picoamps input. Or, 0.1 picoamps per millivolt amplifier output.

In the Eltec equipment setup (see attached drawing), a blackbody at 100 C is placed 10 centimeters from the detector to be tested. The blackbody aperture is 0.873 inches diameter. The chopper (optical modulator) is placed next to the blackbody and the chopper is operated at a 10 Hz rate.

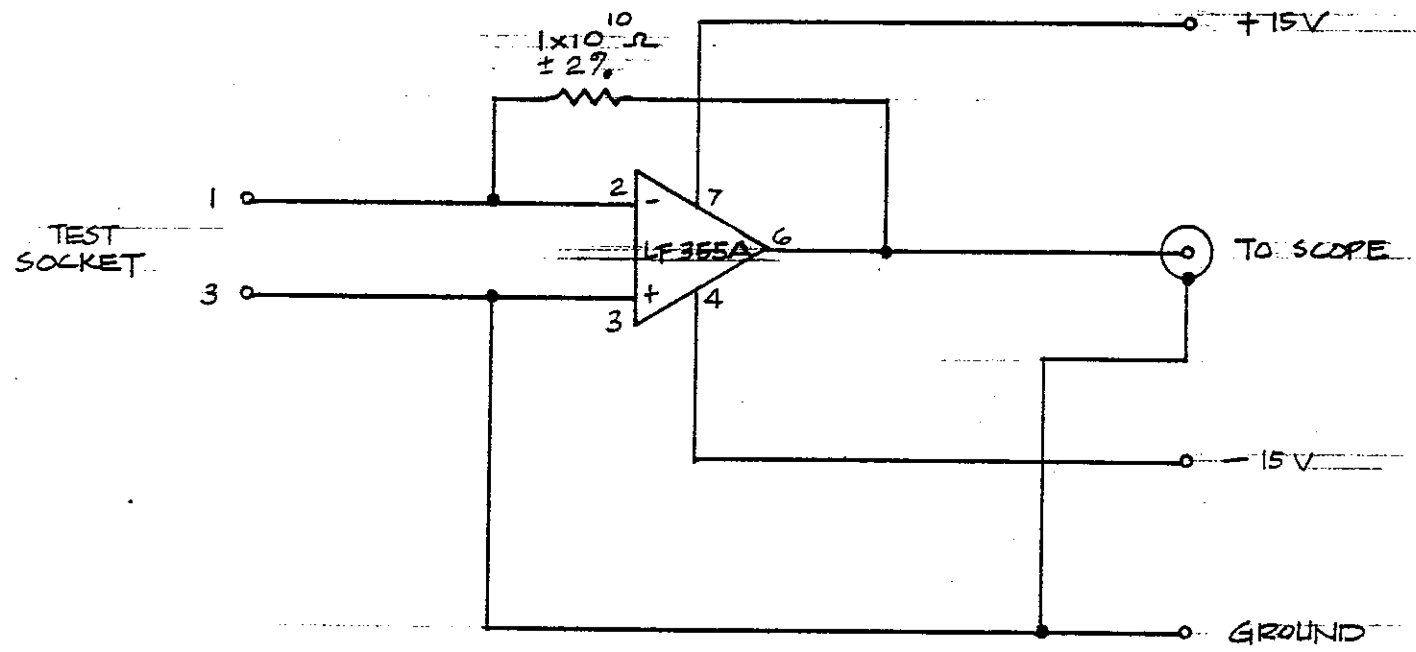
In the setup as described, the radiant contrast flux density at the detector is 8.83 X 10E-4 watts per square centimeter (radiation from 0.65 to 20 micrometers). The power number includes normalization of the chopper form factor at 10 Hz (the chopper does not produce a perfect square wave: corners will be rounded).

The Eltec Model 420-0 Laser Detector has a crystal sensing area of 2.5 X 2.5 millimeters which translates into an area of 0.0625 sq. cm. Thus there is a flux contrast of 5.52 X 10E-5 watts on the detector. In this situation, for a detector without a window, the minimum allowable output from the amplifier for a production run detector is 80 millivolts. The 80 mV equates to a current sensitivity of 0.145 microamp per watt. Since this number is now normalized to 1 watt, the final number is "Current Responsivity".

If the detector were fitted with the Eltec -25 bandpass window (atmospheric window, 8-14 micrometers), much of the radiant flux would be blocked from the sensing crystal. Under the same conditions as before (100 C blackbody, 10 cm distance, 0.873-inch aperture, single slot chopper at 10 Hz), the flux density from 8.3 to 14.2 micrometers <u>at</u> the detector would be 3.73 X 10E-4 watts per square centimeter. The <u>minimum</u> transmittance of the Eltec -25 window is 75%. Therefore, the flux density on the sensing crystal is about 2.8 X 10E-4 W/sq. cm.

Thus for an Eltec Model 420-25 detector, the flux contrast on the 2.5 X 2.5 millimeter crystal is 1.75 X 10E-5 watts. The output from the amplifier would be 25.4 millivolts (minimum) for 1.75 X 10E5 watts which would correspond to a Current Responsivity of 0.145 microamps per watt using the transfer function of 0.1 picoamps per millivolt.

David Cima,
Director Applications Engineering
Eltec Instruments, Inc.



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UNLESS OTHERWISE SPECIFIED	
DIMENSIONS ARE IN INCHES (MM)	
TOLERANCES	
DECIMAL .XX = ± .010 .XXX = ± .005	FRACTIONAL ± 1/64 ANGULAR ± 1°
FINISHED SURFACES RMS BREAK SHARP CORNERS	
MATERIAL	

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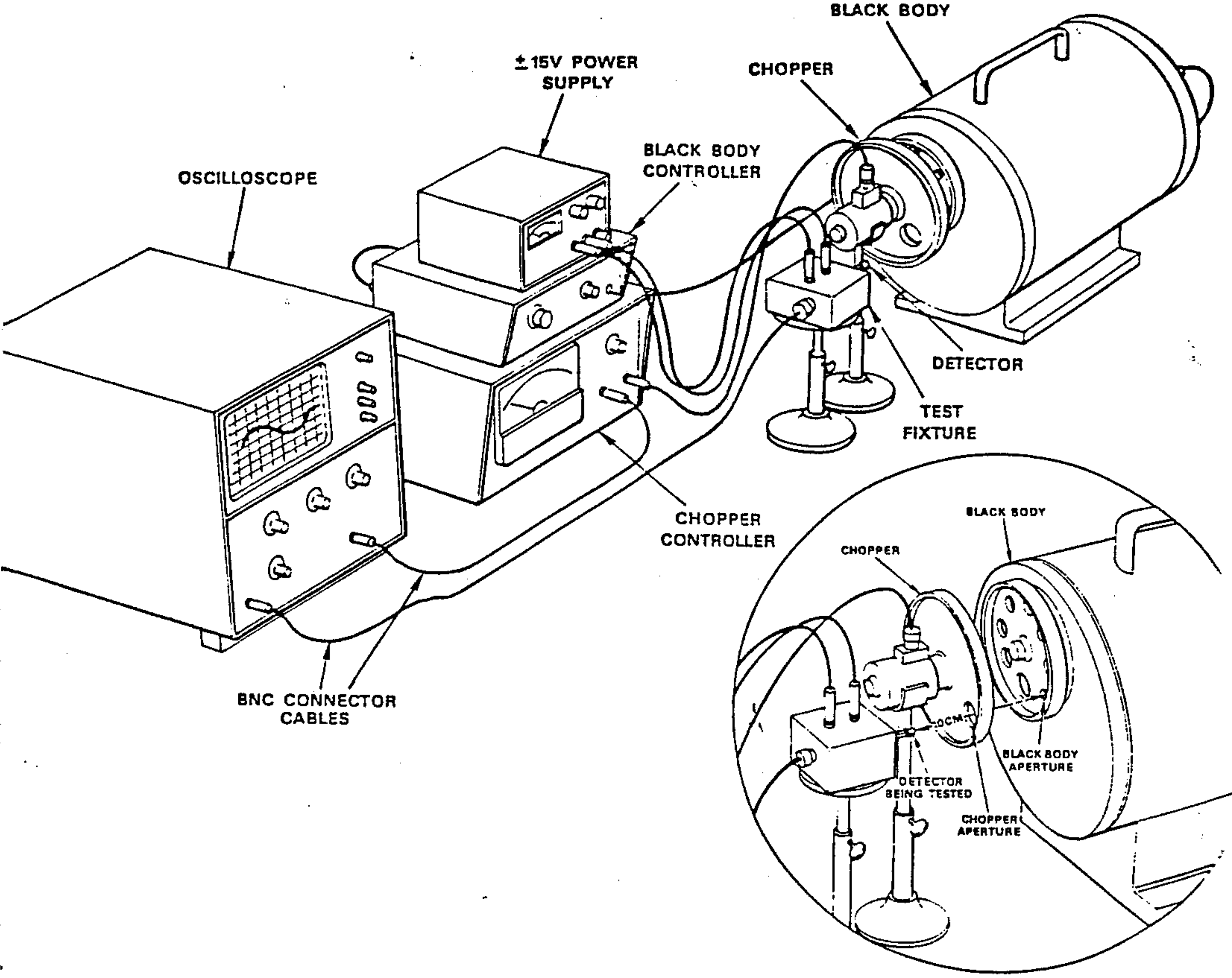
DATE: 11-30-88	APPR. BY: LC 7-31-91		REVISION:
SCALE: N/A	DRAWN BY: RD	CHECKED BY:	SHEET 1 OF 1
420 TEST FIXTURE			
CODE IDENT. NO.	SIZE A		DRAWING NO. 9201168


BLACK BODY
±15V POWER SUPPLY
CHOPPER
BLACK BODY CONTROLLER
OSCILLOSCOPE
DETECTOR
TEST FIXTURE
CHOPPER CONTROLLER
BNC CONNECTOR CABLES
BLACK BODY
CHOPPER
BLACK BODY APERTURE
DETECTOR BEING TESTED
CHOPPER APERTURE