

# INSTRUCTION MANUAL:

## ILT1700 Research Radiometer



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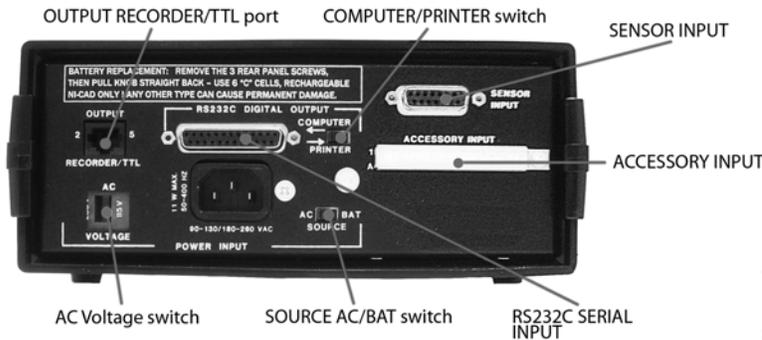
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# 1. Quick Reference Guide

## 1.1 Rear Panel Set Up:



### 1.1.1 International Power Settings

Switch AC voltage selector switch to 220 or 115 VAC as applicable. Select 115 VAC for use on power systems between 90 and 130 VAC (JP, US, CA). Select 230 VAC for use on power systems between 180 and 260 VAC (EC, AU).

### 1.1.2 Power Cord

Connect power cord to power input then into main wall socket. The standard male power plug on the back of the ILT1700 accepts power cords from many different countries and power systems.

### 1.1.3 Select AC Power Source

Switch AC / BAT selector to AC position for operation using an alternating current power supply. The internal lithium batteries will automatically recharge whenever the ILT1700 is plugged into an external power supply. The batteries must initially be charged before the first use on battery power.

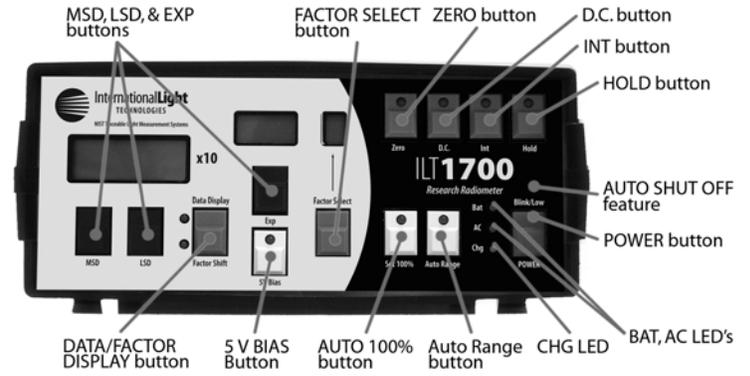
### 1.1.4 Plug In Detector

Connect detector to sensor input via the 15 pin D-Sub-Min connector labeled SENSOR INPUT. The D connector is wider on the top than on the bottom. The plug must be aligned properly with the socket for the two to mate.

### 1.1.5 For More Information

Refer to section 2.2 for more detailed information.

## 1.2 Front Panel Set Up:



### 1.2.1 Turn Power On

Press POWER switch. AC LED indicator should be illuminated. If not check rear panel switch to ensure it is in the AC position.

### 1.2.2 Store Sensitivity Factors

Enter sensitivity factor from detector calibration certificate.

- a. Press Factor Display button.
- b. Press FACTOR SELECT button until 0 appears in window above button.
- c. Enter sensitivity factor by pressing MSD, LSD & EXP buttons. Enter the number and exponent as it is shown on your calibration certificate. This factor is now permanently stored as factor number 0.
- d. Repeat steps b & c for additional factors. Ten factors can be stored in this manner. Remember to increment button to next factor number before entering new factors.
- e. Section 3.2.3.2 & 3.2.3.3 for further information.

### 1.2.3 Display Data

Press DATA/FACTOR/DISPLAY button. ILT1700 is now ready to display data.

### 1.2.4 Bias Selection

Press 5V Bias button if you are using vacuum photodiode type detector (SED240 or SED400), photomultiplier (PM271) or for flash measurements.

### 1.2.5 Zero The Detector

Cover detector with opaque object, wait ten seconds and press ZERO button to zero instrument or zero ambient level as applicable.

### 1.2.6 Select Measurement Mode

Select measurement function by pressing either D.C. button or INT button for continuous or integrated readings. Remember INT will sum up the signal over that integration time and D.C. mode will read the average steady state

## 1.3 Begin to Measure

### 1.3.1 Check the Detector

- 1.3.1.1 Plug a detector into the Sensor Input.
- 1.3.1.2 Select the appropriate calibration factor for that detector.
- 1.3.1.3 Remove the protective lens cap from the detector.

### 1.3.2 Zero the Detector

- 1.3.2.1 Turn off or block the light source that you wish to measure
- 1.3.2.2 Press the ZERO button and hold it for more than a second to get a good stable zero reading.
- 1.3.2.3 Turn on or unblock the light source after the Zero LED turns off.

### 1.3.3 Operating in D.C. Signal Mode

- 1.3.3.1 The ILT1700 default operating mode is D.C. mode. If the D.C. LED is not lit, press the D.C. button to enter D.C. mode. The ILT1700 samples continuously, updating the display every half second.
- 1.3.3.2 To measure as a percentage of a known peak value, first establish the peak condition, then press the SET 100% button. The display now reads as a percentage of the set value.
- 1.3.3.3 To measure within a fixed range, turn off the Auto Range feature by pressing the AUTO RANGE button. The exponent on the display will not change when the Auto Range LED is off. The ILT1700 default setting is Auto Range On.
- 1.3.3.4 Hold a reading temporarily by pressing the HOLD button. This freezes the display for use in a darkroom.

### 1.3.4 Operating in Integrate Mode

- 1.3.4.1 Press the INT button to begin integrating (summing) all readings. This feature is useful for making dose measurements.
- 1.3.4.2 Press the HOLD button to temporarily pause the display. The integration continues, however, allowing you to write down interim readings.
- 1.3.4.3 Press the HOLD button again to continue displaying the ongoing integration.
- 1.3.4.4 Note: the Zero level that you set previously is subtracted continuously from all integrated readings. You can reset the Zero in Integrate mode by pressing the ZERO button in the dark or ambient condition.
- 1.3.4.5 Press the D.C. button to stop the integration.

## 2. Controls

### 2.1 Front Panel



#### 2.1.1 Power Controls

The power controls are located in the lower right hand quadrant of the front panel, outlined by a segregated box marked 'POWER'. Before pressing the ON/OFF button, consult section 3.1 to be sure you have selected the correct power settings for the available input power. There are three LED's and one ON/OFF button. If all the lights are off, the unit is completely turned off. If the 'BAT' light is lit, the power is coming from the six (6) internal 'C' cells. To conserve battery power, the unit will turn itself off after approximately six (6) minutes. If you wish the unit to remain on, you must select one of the next three sources of power, as indicated by the 'AC' light. The choices are from one of three places: 115 volts AC, 230 volts AC, or 8 to 15 volts DC (through the auxiliary input). If the 'CHG' light is lit, the unit is off but plugged into a source of AC or auxiliary power, and the internal batteries are being charged. A blinking battery light indicates a low battery voltage. Either the battery must be recharged or replaced as necessary (see section 3.1.2 for details). CAUTION: DO NOT RECHARGE ALKALINE BATTERIES. If the AC light blinks, the internal power supply voltages are out of regulation, which may mean the line voltage is too low or there has been a component failure in the system.

#### 2.1.2 Function Controls

In the upper right hand quadrant of the front panel are the 'FUNCTION' Controls, consisting of four (4) push-buttons, marked 'ZERO', 'D.C.', 'INT', and 'HOLD'. The unit will start up in the 'D.C.' state, ready to read average steady state light levels. The averaging is done over a period of exactly 0.5 second unless the level is extremely low. At that point, averaging of one second or two seconds will automatically be selected to get a better reading and smooth out unwanted noise.

If you cover up the detector and press the 'ZERO' button, the unit will take a reading of this low level and subtract that reading from all future readings, thereby establishing the 'ZERO' reference condition. This 'ZERO' can be any reference level, such as the ambient room illumination. If an additional light is turned on, the added

magnitude will read out, exclusive of the room lights. BE SURE TO CHECK THE ZERO BEFORE TAKING A MEASUREMENT. Failure to do so is the biggest cause for erroneous readings.

The button marked 'INT' stands for integrate. By pressing 'INT' the unit begins to sum up all the energy over time until you press 'HOLD', which terminates the integration and displays the final results. Integration is also useful for flash integrations and for long term averaging of irregular sources such as arc welding equipment. See section 3.3 for more details on integration.

The button marked 'HOLD' freezes the last D.C. reading or displays the sum of the integration. If you go back into the integrate mode by pressing 'INT', the sum will continue to be added to the previous integration. Pressing 'ZERO' or 'D.C.' will reset the display to zero and put the instrument in the D.C. mode.

### 2.1.3 Readout Display

The user gets readings from the Liquid Crystal Display characters (upper left quadrant of panel), with signal data displayed in either scientific notation or in percentage, and programmed sensitivity factors displayed in scientific notation. In scientific notation, the display gives the mantissa and the power of 10 exponent. The mantissa consists of three and a half digits that range from 1.000 to 9.99. The exponent can range from -19 to +19 which covers 39 decades of readout range. This is more than will ever be needed, but it does allow for large excursions of light level, as well as a wide variation of units used in measuring light.

For example if you wanted to make the system readout night levels of irradiance ( $\text{W}/\text{cm}^2$ ) with a photomultiplier, you might get answers as low as  $1.00\text{e}^{-15} \text{ W}/\text{cm}^2$ . Likewise if you were reading the photometric light level in outer space, it might read  $1.000\text{e}^5$  lux. In these examples the readout had to span 21 decades for two different applications. The letter "e" is used to designate the exponent part (to the base of 10).

### 2.1.4 Display Selector

The button marked 'DISPLAY' with 'DATA' AND 'FACTOR' above and below respectively, is used to select whether the LCD Display will show light readings or the present sensitivity factor in use. There are two lights along the side of this button to show which mode the display is in. This toggles back and forth for each press of the button. The displaying of optical data was discussed in 2.1.3 above. In the 'FACTOR' mode four (4) more buttons become active to select any of 10 different sensitivity factors, or to change any factor (see 2.1.5 and 2.1.6 below).

### 2.1.5 Factor Selector

In the center of the panel is a bracketed area labeled 'FACTOR SELECT', which has a button and a one digit readout. If the 'DISPLAY' mode is set to factor, then the user can select any of 10 different user programmable sensitivity factors (0-9) that could apply to different detectors or to different combinations of detector, filter, and diffuser. These factors are obtained from the calibration

certificate for your particular system. If you want to read out in current (amperes), dial in  $1.000\text{e}^0$ . See the next section for changing factors.

### 2.1.6 Changing Factors

There are three BLUE buttons on the left side of the front panel used for changing the sensitivity factors. They are marked 'MSD', 'LSD', and 'EXP', which stand for Most Significant Digits, Least Significant Digits, and exponent, respectively. The 'MSD' button increments the left two digits of the mantissa, from 1.0 to 9. The 'LSD' button increments the right two digits of the mantissa, from 00 to 99. By holding these buttons down (when in 'FACTOR' mode), the mantissa digits will increment exponentially up to a higher value, from 1.000 to 9.99. The 'EXP' button performs a similar function, incrementing the exponent digit from  $\text{e}-19$  to  $\text{e}+19$ . A full explanation on factor entry is covered in section 3.2.3.2.

### 2.1.7 Bias Voltage

The white button (low center) labeled '5 V BIAS', reverse biases semiconductor detectors with 5 volts, or it adds an additional 5 Volt reverse voltage to any vacuum photodiode for a total reverse selection of 14 volts. In other words, a silicon detector can be operated without any bias (photovoltaic mode) for low level and D.C. readings, or with a 5 volt bias, which increases the speed of response for flash measurements. A vacuum photodiode always needs a bias, so it is wired in the connector to give a bias choice of either 9 volts (5 V bias light off), or 14 volts (5 V bias light on). The bias ON is always the right choice for vacuum photodiodes (see details in section 3.4.1).

### 2.1.8 Auto Range

The white button on the lower right side of the front panel, labeled 'AUTO RANGE', gives the user the option to limit the ranging ability of the system, so one can notice gross changes in readings at a glance due to either the 'HI' indication for too bright, or a very small mantissa for a level too low. The alternate action of this button selects or de-selects 'AUTO RANGE'. If you are over-ranged and wish to re-establish a new level, you must toggle the function into 'AUTO RANGE', then turn off the 'AUTO RANGE' mode again. See section 3.2.2 for more details on the use of this control.

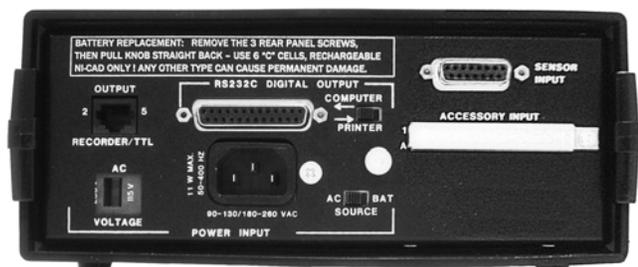
### 2.1.9 Percentage Mode

The other white button in the lower right corner of the panel selects a relative mode by making the display reading equal 100.0, and referencing all subsequent readings to this original value. These readings are a percentage of that original value. This is very useful for making transmission measurements or reflectance measurements directly. You must establish a reference for the 100% value, by removing the filter between the light source and the detector or by using a white reflectance standard for the 100% condition.

There are many applications that require relative measurements, such as attenuation measurements through an optical system, or comparisons between two light sources. For example you could turn on one light and set to 100%.

Then turn that light off and turn the unknown light on to read the relative value compared to the first lamp. Since percentage mode disables the auto-range, the largest relative reading possible is 1999% and the smallest is 0.1%.

## 2.2 Rear Panel



### 2.2.1 AC Voltage

In the lower left hand quadrant of the rear panel is a switch to select the A.C. power available in your area. The two choices are 115 Volts AC, which is common throughout most of North America, and 230 Volts AC, which is common throughout most of Europe. In some parts of the world (Japan, for instance), the common voltage is 100 VAC, which is accommodated on the 115 VAC selection. You make a selection by inserting a pointed tool, such as a screwdriver, into the slot, to slide the switch left or right (115 or 230 volts respectively). The selected voltage shows up in the switch window to confirm your choice.

### 2.2.2 Power Input

Just to the right of the voltage selection switch is the 'POWER INPUT' connector. This is an international type of connector to accept the source of AC power. We provide a cable with an American type of plug on it. You may have to cut this plug off and replace it with one which is acceptable in your area. If you need to do this, be advised that the green/yellow wire is the GROUND (earth) line. The blue wire is the 'NEUTRAL', and the brown wire is the 'LINE' or live wire.

### 2.2.3 Power Source

To the right of the power input connector is a slide switch marked 'AC/BAT SOURCE'. This allows the user to select either internal battery operation (BAT), or external power from either Alternating Current (AC) or D.C through the auxiliary input. On the BAT selection, the instrument will turn itself off, in approximately six (6) minutes, to conserve battery life.

### 2.2.4 Recorder / TTL Output

In the upper left side of the rear panel we have the modular jack marked 'OUTPUT RECORDER/TTL'. This jack provides the user with two types of output, both digital and analog. A 25 foot cable accessory is available (model number A403) to make the output accessible at a remote location. See sections 4.2 and 4.4 for details.

### 2.2.5 RS232C Digital Output

To the right of the 'OUTPUT' jack we have the other digital output interface marked 'RS232C DIGITAL OUTPUT'. This is an industry standard serial interface which can be configured as a DTE or DCE device by selecting the slide switch to the right of the 25 pin DB25 connector. The right position of the switch marked 'PRINTER' puts the instrument into the DCE configuration, normally used to go to a printer. When switched to the left, the instrument becomes the Data Terminal Equipment (DTE) for normal use with computers. There are exceptions to this rule, so you may have to experiment to match your configuration.

### 2.2.6 Sensor Input

In the upper right hand corner of the rear panel is the 15 pin connector marked 'SENSOR INPUT'. This, of course, is where you plug in the light sensor or special transducer for measuring another parameter. The correct internal voltages for all International Light detectors are provided in the hardware. For special customer supplied input devices, you may purchase the A408 accessory cable to permit both negative current measurements or conductance measurements from a nonstandard transducer (see section 5.1.2 for more information on this).

### 2.2.7 Accessory Input

Below the sensor input we have the 24 pin card edge connector marked 'ACCESSORY INPUT'. This port is used for remote control applications, spectroradiometer systems, production tests, and for future new product developments (see section 6.0 for more on this).

### 2.2.8 Battery Replacement

In the very upper left corner is a printed message which gives a brief description of how to insert or replace the internal batteries. The back panel is tricky to remove, especially on new units, because everything fits tightly. You must remove the three nickel-plated Phillips screws. Notice that one screw is larger than the other two screws. The larger screw goes to the right of the power input connector. Next, you must pull the back panel to the rear by pulling on the chrome plated knob with a pair of pliers. To avoid marring the knob, we suggest you put tape on the knob before you grasp it with the pliers. While pulling, you should direct your force up and down to work the assembly to the rear. Be careful when it lets go, so you do not allow it to move too rapidly. There are two battery wires that could be broken if care is not used. Also be careful to notice if one of the circuit boards is pulled back with the rear panel. It should NOT be pulled back. Free the board from the rear panel and carefully push the board back into position so it is even with the one above it. Set the rear panel assembly on a table close to the unit without stretching the two wires. You will now have free access to the battery compartment which holds six (6) 'C' cells. We recommend either rechargeable nickel cadmium batteries that are available from us (A404) or standard alkaline batteries.

# 3. Operation

## 3.1 Power Selection

The ILT1700 can operate from seven different sources of power as follows:

- Six internal NiCad 'C' cells (I.L. accessory A404)
- Six internal alkaline 'C' cells (available locally)
- External d.c. power supply or battery (8 to 15 VDC, use A402)
- Mobile power (thru cigarette lighter, use cable A401)
- 115 VAC/50-400 Hz (Power cord supplied)
- 100 VAC/60-400 Hz (Change plug on power cord, if necessary)
- 230 VAC/50-400 Hz (Change plug on power cord)

Due to the varied applications and the world wide market, it has been necessary to offer a very universal instrument as far as power selection. The internal batteries are necessary for any application which requires on site inspections or site surveys, such as health hazard or field study applications.

External mobile power may be used to recharge the internal rechargeable batteries via a vehicle's cigarette lighter outlet, or the instrument may be powered directly from the vehicle. On occasion, an instrument must be used at a remote location where only a DC source of power is available. Typical applications might be in space vessels or in long term remote environmental stations that are solar powered. Last but not least, we will mention the most common power source: the locally available AC power from the line outlet. Several choices of input line voltage make the ILT1700 usable any where in the world.

### 3.1.1 AC Power

Section 2.2 described the location of the power socket (connector) on the rear panel. The ILT1700 is supplied with two meter (7 feet) power cord that has the appropriate connector to mate with the instrument on one end and a plug that is approved in North America for compatibility with a standard 115 VAC wall outlet. This makes it very simple to become operational in the United States or Canada on the standard 115 Volts AC. Before applying power, be sure to check the rear panel slide switch marked 'AC VOLTAGE' so that '115' is showing in the window. If the switch needs to be changed, use a screw driver to place in the slot. Move to the left for 100 or 115 and to the right for 230 volt AC operation. In Europe and many other parts of the world, the standard available power is 230 volts AC. To prepare the instrument for these areas, you must cut the plug off of the power cord that was supplied with the system and strip back the insulation to reveal three color coded wires. The green/yellow is earth 'GROUND', the blue wire is the 'NEUTRAL', and the brown wire is the live wire referred to as 'LINE'. Attach these wires to a plug that is approved in your area. Be sure to switch the slide switch to the right for

the '230' position. The instrument draws less than 11 watts, (about 10% of that consumed by a standard light bulb), so it can be used on very low power circuits.

### 3.1.2 Internal Battery Power

The second most common source of power is from internal batteries. For many applications, it is necessary to carry the instrument around to survey different areas. In these cases you would want to insert one of two types of batteries. The first type is alkaline 'C' cells, which are the easiest to obtain locally and will run the instrument for the longest duration (approximately 10 hours). Since the instrument turns itself off in 5 to 10 minutes, this will permit more than 75 measurement sessions, assuming the user forgets to turn the instrument off each time. In most real cases, the battery shelf life will be a more limiting number, providing a battery life of about two years. The second source of power would be from six rechargeable nickel cadmium batteries, available from International Light as accessory number A404. These batteries will run the system for about five (5) hours on one charge, which is approximately 50 measurement sessions. Recharging can be done overnight (14 hours) from either the AC line voltage or from mobile power via the cigarette lighter cable (accessory A401). The recharging concept has a higher initial cost, but provides many more years of service before battery replacement. The actual replacement can be accomplished by following the directions outlined in section 2.2.8.

### 3.1.3 External Mobile or Battery Power

External DC (direct current) power may be applied through pin 'C' of the accessory connector in the voltage range of 8 to 15 volts, where pin 'C' is positive, and pin 1 (or pin A) is the ground pin. We offer the mating card edge connector (accessory A402) and another accessory (A401) which has the connector, cable and cigarette lighter plug to be used in most vehicles. This input is protected for reverse polarity, and handles a very large range of direct current. The ability to accommodate such a wide range permits use of even a solar battery that is nominally rated at 12 volts, yet varies substantially. Mobile power may be used to recharge the internal nickel cadmium batteries, making extended field use possible where AC power lines are not available. Another reason for using the external power is to avoid the automatic timed shut off. If field measurements are to be made throughout the day, an external battery (such as a 12 volt lantern battery or car battery) can be hooked up to the ILT1700 to run the unit for about three weeks at 9 hours a day.

## 3.2 C.W. Measurements

The 'C.W.' stands for 'Continuous Wave', which is also referred to as D.C. Measurements (a carry over from the electronics field, meaning Direct Current). In other words, we are referring to those measurements where the magnitude of the light level remains reasonably stable when averaged over any half second interval. The light output from a fluorescent lamp actually consists of pulses emitted 120

times per second (twice the line frequency), but we consider that to be C.W. since our eyes cannot detect the flicker. The instrument is similar to the eye, in that it integrates for a half second, displaying the average over that interval. If this average is repeatable, we will get the same reading on the instrument over a long measurement interval.

### 3.2.1 Zeroing

One of the most important controls on this instrument is the 'ZERO' button, since it can cause the most amount of confusion when it is not understood. This button does not do an internal zero, as some users might expect. It actually subtracts the present reading from itself and from all future readings. It also remembers this condition even if the unit is turned off. That means if the previous user set the zero to subtract a large amount of light, it will continue to subtract that same magnitude until you correct it. This can be a very powerful control if used correctly. For example, let's suppose you want to make a measurement of a sample light source, but you do not want to turn the room lights completely off. One method would be to make a measurement with the unknown light on, and a second measurement with the unknown off, and subtract the two from each other to give you the difference, which will be the value of the unknown source. We provide this capability automatically, without the external subtraction.

Simply press the zero button when the unknown is off. Turn the unknown on and read its contribution directly on the meter. If your requirement is to read all the light present and you want the best possible zero, you must cover the detector with an opaque object (or place it face down on an opaque surface), wait ten (10) seconds, and press the 'ZERO' button. It takes several seconds to produce a low level zero due to the ranging over several decades plus the automatic extension of the sampling time when the signal gets small for increased sensitivity. This sampling can be as long as two (2) seconds and requires several sample periods to go down to its most sensitive range. If you are impatient, you can watch the exponent drop down three (3) decades below the level you want to measure. Then press 'ZERO' even though the number does not read zero, because it will be less than 0.1% of the level you are about to read, which is good enough for accuracy of one part in a thousand. For an absolute zero, you must have the detector covered extremely well to seal all light leaks, and then you must wait the full 10 seconds before the system settles down to the lowest level, before pressing the 'zero' button. Another technique is to switch the auto range off when you are exposed to the light to be measured. Now cover the detector and press the zero button when the reading stabilizes. This will occur much quicker because the system will not range many decades down below the actual level to be measured. This sounds more complicated than it really is. Within a short period of time, you will perform these steps instinctively.

### 3.2.2 Range Selection

Most users will find the auto range mode the best choice when using the Radiometer. This is the initialization default mode which will display any magnitude automatically, as

long as a proper previous zero had been performed (see the previous section) and the correct sensitivity factor is programmed and selected (see the next section). There are two other range choices, that may apply for special reasons. If many repetitive measurements are to be made, it is often desirable to turn the auto range mode off, which essentially freezes the range exponent, so the user is alerted to a large change in signal by the fact that the mantissa will either show several zero digits, for a low reading, or will read 'HI', to indicate an upward range change. In scientific notation, you could experience a tenfold change in the light level, which might go unnoticed because the exponent is the only obvious digit that changed. By turning the automatic feature off, it becomes more obvious that a significant change has occurred. Another reason to turn the auto range off is to read a zero that occurs quickly as described under 'zeroing in section 3.2.1 above. The third range choice is 'percent mode', and is described in section 3.2.4.

### 3.2.3 Programming

The Radiometer performs subtraction, as mentioned in the zeroing section (3.2.1). It also calculates ratios as will be described in the next section (Percent Mode), but for most measurements it is required to scale the answers by a sensitivity factor in order to read directly in your desired optical units. This scaling is done internally by dividing the electrical current coming from the input device by one of ten (10) sensitivity factors, and then displaying the result in floating point arithmetic, on the front panel. These answers can range from  $0.00 \times 10^{-19}$  to  $9.99 \times 10^{+19}$ .

3.2.3.1 Current Measurements - If you want to read the electrical current, you may select a factor of  $1.00 \times 10^{+0}$  (which is 1). The answer will be displayed in amperes. These are good units for any sensor that is not calibrated, because a subsequent calibration would permit you to reconstruct the absolute data. The best policy is to obtain a calibration sensitivity factor for the detector assembly at the time of purchase, so that direct answers can be obtained immediately.

3.2.3.2 Entering Factory Calibrated Factors - The factory calibration provides a sensitivity factor that appears on the calibration certificate in units with amperes (A) in the numerator and the desired readout units in the denominator. When the instrument divides the current (amperes) by this factor, the ampere term drops out leaving the final desired optical units on the display.

You may store ten factors (in registers 0 to 9) for future selection. Each factor is designated by a number in the factor select window. (See 3.2.3.3 below for more on factor selection.) We suggest that you store  $1.000 \times 10^{+0}$  as one of the entries, for reading in units of current (amperes see section 3.2.3.1 above). You should also record any extra factors for different units, etc. on your calibration certificate.

To enter a factor, turn the instrument on, toggle the 'DISPLAY' button to 'FACTOR', then increment the 'FACTOR SELECT' to read the register you wish to change (0 to 9). Now use the three blue buttons marked

'MSD', 'LSD', AND 'EXP' to enter the number in scientific notation, just as it appears on the calibration certificate. By holding a button in, the display will begin to roll faster, so you can rapidly increment to a number some distance away. As you approach the desired number, pulse the button one step at a time.

3.2.3.3 Sensitivity Factor Selection (0-9) - The last window is the 'FACTOR SELECT' readout. It shows the user which of 10 stored factors has been selected. Several different detectors and/or combinations of detector, filter, and diffuser can require several factors for different measurements. Also at different wavelengths there may be different sensitivity factors, so the wavelength would determine the 'FACTOR SELECT' number used. This is changed by switching to the 'FACTOR' mode on the DISPLAY switch, and then incrementing the 'FACTOR SELECT' button to arrive at the desired factor number.

3.2.3.4 Self Calibration Technique - These factors may also be used for customizing readouts in relative units that pertain to your particular system. For example; an optical throughput, in a hypothetical system, may be adjusted at the factory to a particular magnitude, such as 150 ( $1.500e^{+2}$  on display). By selecting the right factor, you can make the instrument also read 150 for that desired magnitude. The ILT1700 can then be used for a subsequent quality control check to adjust production units to have the same nominal output. Another relative application could be to obtain a precise correlation between departments. A standard source would be used as a reference so all measurement systems would be set to read the same from the same source. This type of 'in house' calibration can provide an accuracy better than one percent, without having to refer back to the reference source very often, especially since silicon detectors are generally more stable than standard sources.

Self Calibrating Procedure:

A. Enter the ultimate display reading into one of the 10 factor registers, by pressing the DISPLAY button to 'FACTOR' mode, and by using the blue buttons to enter the number (in scientific notation).

B. Switch back to the 'DATA' mode and take a reading. Record this on paper for the next step. As part of the step, be sure your ZERO was still valid before taking the reading.

C. Enter the reading just recorded on paper from step 'B', into one of the 10 registers as you did in step 'A'. You can use the same register since the last number is no longer needed.

D. Now switch back to the 'DATA' mode again and read the same optical signal. It should display the number you were trying to calibrate to in the first place.

### 3.2.4 Percent Mode

There are two very common optical uses for the percent mode, transmission and reflectance. Both measurements require the use of a stable light source. By stable, I mean that it will remain constant during the measurement procedure. Modest accuracy can be achieved with a line powered lamp, but for good long term repeatability, the source should be regulated by an electronic regulator. The

visible output from an incandescent lamp changes 3 % for each 1 % change in voltage, which puts a greater demand on the regulation accuracy. The first step is to set up baffles so the light travels directly from the lamp to the detector, and not via a reflection from some other surface. The second step is to put an aperture between the light and the detector that is smaller in diameter than the size of the sample filter to be measured. Next make an opaque shutter that can be put over the aperture to make a zero measurement. With the light cut off, press 'ZERO'. Now remove the shutter without moving any of the baffles or aperture. Press 'SET 100%', which will be your reference condition. The meter will read 100.0 at this time. Now tape or mount your sample filter over the aperture (again without changing the physical location of baffles or aperture), and read the transmission directly on the ILT1700.

There are many spectral factors that must be considered when making a transmission measurement. If you want to know the transmission at one wavelength, it will be necessary to use an interference filter to establish monochromatic light before inserting the unknown filter. A lamp plus monochromator can be used to create a tunable monochromatic source, for making a full spectral transmission plot of the sample filter. A 100% reading must be established at each wavelength since the source/monochromator combination will not be constant at each wavelength. Often it is required to determine the attenuation of an unknown filter material for a particular source used in your system. In that case the only way to get the same spectrum, is to duplicate the light used in the system in question. (Reflectance and system throughput are two more examples of uses for the percent mode. See section 8.5 for details.)

### 3.2.5 Readout (Scientific Notation)

Most people with a technical background are completely familiar with scientific notation, and will have no difficulty interpreting the data on the display. For the remaining users and as a review, we will briefly describe the notation and how it relates to the readout.

There are two major parts to the readout: 1) The mantissa is a three and a half ( $3 \frac{1}{2}$ ) digit detailed portion of the answer. It is designed to give at least 3 digits of resolution, with the smallest increment less than one part in 200 for a readable answer better than 0.5%. 2) The second part is the exponential portion, that tells which decade the mantissa belongs in. In other words, the exponent is a multiplier by powers of 10. If the exponent is zero, you would multiply by ten raised to the zero power, which is the same as multiplying by one. Likewise, an exponent of three (3) would mean you multiply by one thousand (1000), and so on. This system is necessary to handle the extremely large change in light magnitude, and the tremendous variation in measurement units. As an example, your eye can see in an environment which can have a brightness change of one million to one. If you couple this with the variety of optical units, you can span more than 21 decades of readout. Our instrument has been designed with the

ability to display magnitudes over 39 decades, just in case you come up with a new variation. When in the 'FACTOR' mode, the display also reads out in scientific notation, which is the same as presented on the calibration certificate.

There is one more mode of readout which is the percent mode. By pressing 'SET 100%' the system will read in relative units, referenced to the magnitude existing when the 'SET 100%' was pressed. The exponent will not be used in this mode of operation, and auto ranging is turned off. Relative changes in light level will be displayed in percentage.

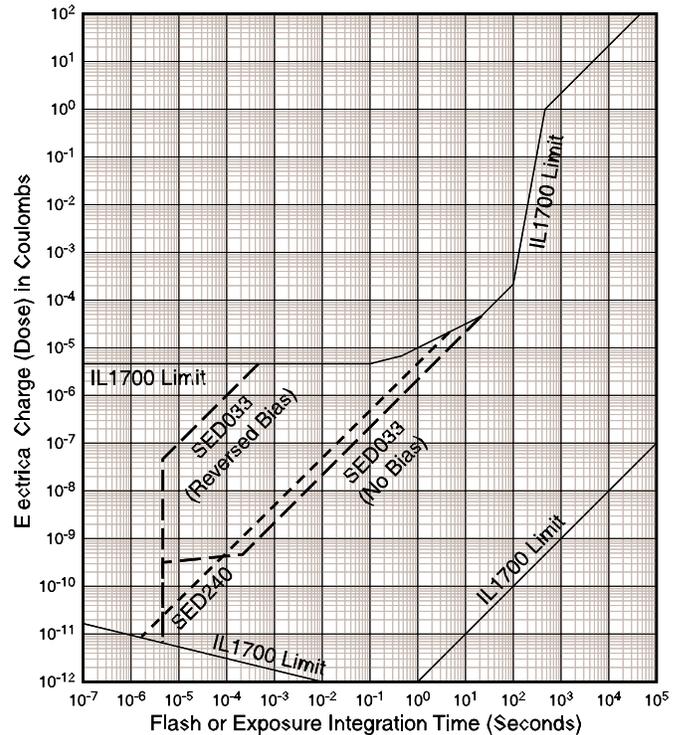
### 3.2.6 Darkroom Readings

The liquid crystal display has very good visibility in bright environments such as sunlight, but since it relies upon reflectance of available light, it will not readout in the dark. We considered building in back lighting, but that would not permit battery operation and it would create unwanted light in a darkroom environment. Our solution was to locate the 'HOLD' button on the right hand side of the instrument, in a location that can be easily found in the dark. With your fingers along the right side of the instrument, you can press the hold button when in total darkness. The room lights can then be turned on, or a small flashlight can be used to read the display, after the sensitive detector is appropriately covered (if necessary). The display will hold the reading present when the 'HOLD' button was pressed. This feature also applies to flash integrations, where the final integral will be held on the display until another function button is pressed.

## 3.3 Integration Measurements

The ILT1700 is capable of integrating the energy in a flash of light at microsecond speeds, as well as integrating for over eighteen years, plus everything in between. In addition, it is capable of automatically handling the ranging, without knowing in advance how long the integration period will be. Obviously there are some hardware limitations, but not as many as might be expected. The following chart shows the charge conditions that can be measured. This logarithmic chart (below), covers a very large dynamic range, which is misleading at first glance. On the lower right side of the chart the instrument is limited by detector dark current. On the lower left side, the limitation is due to charge insufficiency. The upper left corner is restricted by peak current limitations of the detector. The upper middle is limited by the conversion rate of the instrument. Finally the highest charges (upper center), are limited by maximum detector current again. Even with all these boundaries, the ILT1700 operates over more than six (6) decades of charge ranges and more than a dozen decades of time ranges, which we believe to be the greatest dynamic range of any available system. To relate this chart to optical measurements you must multiply the energy you wish to measure, in units of either Joules or Joules per square centimeter, by the sensitivity factor of your detector. This product will give

the charge that can be plotted on this chart. By the way, a Joule is equal to a Watt\*second, in case your units are broken out into the power component.



### 3.3.1 Integration Zero

A 'zero' state for integration is when the first derivative of the output is zero. In other words, a non-changing output. To get this state, the integral of any unwanted input signal must be measured and subtracted from the integral of the total signal. 'Unwanted' can mean ambient light or some detector dark current contribution. An example may be the best way to shed some 'light' on the subject. Suppose we are in a room with two table lamps in it, called 'A' and 'B'. 'A' is left on so you can see what you are doing, and 'B' is the unknown lamp to be measured. With 'B' off, you would press 'ZERO' so the signal dose from 'A' will be ignored. The ILT1700 must measure this incoming signal from 'A', which will subsequently be removed from the total integral. This requires subtracting the product of 'A' times the integral time from the total integral produced by 'A' and 'B' together. Fortunately, this is all done for you by the internal computer. Another thing that is done automatically is the zeroing of the dose accumulation registers at the time you press the 'INT' button. If you zeroed on 'A' and never turned 'B' on, the accumulated dose should be essentially zero, or equal to any small change in 'A' as compared to its value when the 'ZERO' button was pressed. This change can be positive or negative, depending upon whether 'A' got a little brighter or dimmer, respectively. It is reasonable to make sure your unknown dose is much greater than any zeroed dose, to be sure that small changes in the ambient

will not effect the accuracy of the final result. A good rule of thumb is to try to keep your signal contribution at least 10 times larger than the ambient contribution. This may require working in the dark, which can be done by either remote control from another room or by pressing the hold button while still in the dark, and then taking the data with the lights turned on (See section 3.3.6 for more on this).

### 3.3.2 Flash measurements

The procedure for making flash measurements requires the use of three other function buttons. We start with the '5V BIAS' button. IT IS NECESSARY to reverse bias the detector to make the detector respond faster, as well as to be able to handle the high peak currents without saturating and also to provide bias compliance to an input charge circuit which temporarily holds the charge long enough for the precision charge measurement to be performed. In other words the red '5V BIAS' LED should be lit when making any flash measurement at speeds faster than one second. The 'ZERO' button is used to cancel out any unwanted ambient contribution that is present before and during the flash (see previous section). Next, press the 'INT' button just before the flash is to occur, or if you wish, you may use the 'FLASHnot' output line (pin 9) to activate the flash event (see section 6.1 for details). The summation registers will be instantly zeroed and the integration will commence. Two and a half (2.5) seconds after the flash, press the 'HOLD' button to freeze the final result. This extra time is required to fully dump the charge from a temporary holding circuit on the front end of the input system. This permits high speed measurements to occur faster than the computer can keep up with the input. This feature allows the system to handle 6 decades of high speed charge ranges at a sacrifice of summation speed. In fact, it can take up to 2.5 seconds to produce a final answer to 0.1% resolution. This does not pose any difficulty in any application that can operate in a 'one-shot' mode. However, if there are multiple flashes, you must use a shutter to capture one flash, or integrate for a known number of flashes, and divide the answer by that number. Often it is possible to turn off the power supply to the flash lamp after the required number of flashes has occurred. This will permit the summation time (2.5 seconds) to occur.

### 3.3.3 Long Term Integration

Any integration longer than one second is considered long term integration. In this state, the ILT1700 keeps up with the incoming signals, and presents an updated readout of the progress every 1/2 second. The 'ZERO' button is pressed when looking at any unwanted ambient condition that is NOT to be measured. If you wish to read all the light seen by the detector, then cover up the detector to perform a 'ZERO'. As soon as the 'INT' button is pressed, the integration begins. When the 'HOLD' button is pressed the integration ends and reads out the final integral. If you wish to continue integration without restarting from zero, adding the new dose to the old dose, just press 'INT' again, and 'HOLD' when you want to stop. If you want to start over again from zero, then press 'D.C.' or 'ZERO' before the

'INT' button. If you press 'INT' two times in a row, the system will start a new integration at the time of the second press. This can be useful for multiple exposures, assuming the light is momentarily off to permit time for readout or transfer to a computer or printer. A press of 'INT' starts the next cycle without any other buttons being pressed.

There is no limit to how long you can integrate. The totalizing system will maintain perfect accuracy for over 18 years even if the signal is the maximum permitted into the Radiometer. Obviously there could not be any power interruptions during that time. One possible application for this is in environmental studies which would monitor the solar radiation daily via a telephone interrogation from a central computer. The previous days total would be subtracted from the present total to obtain the one day contribution. The point is that there is no loss of accuracy for extended integrations, and the auto ranging keeps track of the magnitude no matter how big it gets.

### 3.3.4 Averaging

As mentioned above on the subject of multiple flashes, the system can be used to find the average of many flashes. This is done by integrating throughout many flashes. By maintaining a count of the flashes and dividing by that number, you will arrive at the average output from one flash. Another form of averaging is that which occurs as the result of a very irregular light output. An example of such a source is an arc welding process. If you wished to find the average ultraviolet dose the welder might receive during a work day, you could leave the Radiometer running in the integrate mode all day long, or you could integrate for a reasonable length of time to determine the dose for part of a day, then multiply by the number of daily portions representative in the work day to find the total accumulation.

### 3.3.5 Readout (Scientific Notation)

The display reads the total dose in scientific notation (see section 3.2.5 for an explanation). When integrating, the readout is a summation of light over a period of time. The units of readout become the product of the Illuminance or Irradiance times time. As an example, suppose you were integrating to determine the exposure for UV curing. The detector would be reading instantaneous irradiance in units of Watts per Square centimeter ( $W/cm^2$ ), but the exposure would be in 'Watt seconds per square centimeter' ( $W*sec/cm^2$ ), and since a Watt second is equal to a Joule it would be in Joules per square centimeter ( $J/cm^2$ ). If you are dealing with small doses, the answer may be expressed in millijoules per square centimeter ( $mJ/cm^2$ ), by multiplying the answer by 1000, and similarly in microjoules per square centimeter ( $\mu J/cm^2$ ) by multiplying by 1,000,000. For example if the instrument displays ' $1.234e^{-2} J/cm^2$ ', you can multiply by 1000 to get  $12.34 mJ/cm^2$  as your answer.

### 3.3.6 Darkroom Integration

The procedure is similar to that described in section 3.2.6 for continuous light measurements. When integrating in the dark, you must find two buttons. The first is the 'INT' which can easily be found by placing the palm of your

hand on the right side of the instrument and feeling over for the second button from the right with your thumb. In a similar manner, you will locate the 'HOLD' button to stop the integration. This is the easiest to find since it is the first button in from the right side. Once 'HOLD' has been pressed the lights may be turned on to make the readout without changing the reading. It is also possible to operate the instrument with a remote cable from another room, and to print the answers on a small printer such as the A411, or by sending the data to a computer over the RS232C interface (see sections 4. & 6. for more on this).

### 3.4 Bias Selection

As mentioned in section 2.1 (front panel controls), there is a bias button labeled '5V BIAS'. This raises the input node of the input amplifier up to +5 volts which, in turn, reverse biases a silicon detector with 5 volts. If it is a vacuum photodiode, it adds another 5 volt bias to the 9 volts that is already applied to the cathode of the phototube, making the total reverse bias of 14 volts. See the following sections for more details.

#### 3.4.1 Vacuum Photodiode Bias

Vacuum Photodiodes always require a bias voltage to operate properly. All of the International Light Vacuum Photodiodes will operate properly with a bias between 9 and 75 volts. We recommend operating them at the 14 volts provided with the bias ON, so the readings correlate with our calibration lab, and with previous instruments that applied 12 and 15 volts. Another advantage to the larger voltage is the improvement in peak current capability, for maximizing the dynamic range of flash measurements. The difference in D.C. readings between 9 and 15 volts bias, is only about 1%, but to gain that extra accuracy, use it with the '5V BIAS' light on.

#### 3.4.2 Flash Bias

Detector bias has the most significant effect on system performance in flash measurements. Semiconductor devices gain in three ways when placed in a reverse biased condition, as opposed to the photovoltaic mode (zero bias). The first improvement is to reduce the junction capacitance, which makes the instantaneous photo current get to the photometer faster, rather than being delayed as a junction charge. The second improvement is the elimination of junction saturation. This happens because the instantaneous photocurrent produces an  $I \cdot R$  drop across the top transparent electrode, which in turn allows the junction voltage to become forward biased, causing junction saturation. The third advantage has to do with the method used to measure the charge from a flash. In order to make the radiometer operate at speeds faster than the clock time of the computer, it is necessary to temporarily store the flash charge, so the charge digitizing circuitry can withdraw this charge and measure it. This temporary storage can handle  $2.00 \times 10^{-6}$  coulombs, so the instrument maintains 6 decades of dynamic range even down to nanosecond speeds. Below 100 microseconds the limitation is due to the peak current of the

detector, not the instrument. Our SED033 is designed to handle more than 20 milliamps, to still provide 3 decades of useful range at 1 microsecond. By combining this basic capability along with a neutral density attenuator, one can make fast measurements, spanning four or five decades. Anything below one microsecond is not recommended, since a multitude of detector speed limitations, including impedance matching etc., cause inaccuracy.

#### 3.4.3 Low Level Bias

When making low light level measurements, it is important to minimize the detector leakage current. With a semiconductor, this can be done by using it in the photovoltaic mode, with NO BIAS on it at all. This also minimizes the temperature effects on the detector due to changes in the internal shunt resistance. Vacuum Photodiodes must always have a bias on them, so they should be operated with the '5 V BIAS' light ON. As part of the detector design, we have minimized detector leakage through the coaxial cable by keeping the current carrying lead at the same potential as the shield lead, even in the reverse bias mode. Vacuum Photodiodes have a good low light level attribute, the absence of 1/f noise. This low frequency (thermal) noise, can be a serious problem for D.C. measurements when using semiconductors. The vacuum photodiode noise advantage tends to compensate for the higher semiconductor responsivity, making them continue to be a very effective transducer, especially for the short wave length measurements in the UV, and for their ability to reject the longer unwanted wavelengths.

# 4. Outputs

## 4.1 LCD Displays

There are actually 12 positions that are computer controlled on the LCD Displays, assuming you count the signs and the decimal points. These are divided up into 8, 3, & 1, for the Mantissa, the Exponent and the Factor selection, respectively.

### 4.1.1 Mantissa (3 & 1/2 digits plus sign)

If we ignore the decimal points, the main LCD Display presents numbers that range from (+/-) 0 to 1999, which is commonly referred to as three and a half digits. The auto ranging capability in the instrument is used to try to maximize the readability of this display, by keeping the number above 199. In this way, the readout is always going to have a resolution better than 0.5%. If the auto ranging is turned off, the number is allowed to drop down to zero. To complete the scientific notation format, the mantissa display presents the sign of the magnitude and always keeps one significant digit to the left of the decimal point. When in percent mode, the Mantissa display moves the decimal point to any of three positions to display numbers that range from 00.00 up to 1999 percent.

### 4.1.2 Exponent (1 & 1/2 digits plus sign)

To be able to span a very great range of light magnitudes, it is necessary to present the answer in scientific notation. The mantissa above would be lost without the exponential terms to determine the magnitude range in powers of 10. The number 10 is raised to the exponential value shown in the exponent window. It can range from -19 through 0 to +19, covering 39 decades of magnitude change. This may sound like it is much more than needed, but we have already had requirements that use 22 of the 39 decades, due to the wide variety of light measurement units, and the extremely wide dynamic range of user measurement needs.

### 4.1.3 Sensitivity Factor Designator (0-9)

The last window is the 'FACTOR SELECT' readout, which shows the user which of 10 stored factors is selected. These factors are held in 10 registers that remain stored even when the power is turned off. The LCD factor designator tells you which factor has been selected out of the 10 choices from 0 to 9. See section 3.2.3.2 for more on changing these factors.

## 4.2 Recorder Output

An analog output voltage is available on pin 3 with respect to ground (pin 4), through the modular jack on the rear panel. This accepts a standard RJ11 type telephone plug, or may be accessed using our twenty five (25) foot accessory cable (A403), which terminates with colored spade clip leads marked RED (pin 3) which is the plus lead, and GREEN (pin 4), for the ground return.

### 4.2.1 Voltage Range

The voltage is designed to be compatible with most strip chart and X-Y recorders, and yet provide a large enough signal to avoid excessive noise pickup. For these reasons, we have selected a range from 0 to 1.0 volt (1000 millivolts). The output will be a voltage that is exactly 10% of the reading of the mantissa. In other words, a mantissa reading of 7.65 would produce .765 volts. If the unit auto ranges (front panel readout of > 9.99 or < 1.000), the recorder output increases or drops by a factor of ten, so the chart scale will stay between 100 and 1000 millivolts, so as to avoid chart recorder overrange. By keeping track of the number of times the plot makes a 10 to 1 range change, it is possible to know your absolute value on each range.

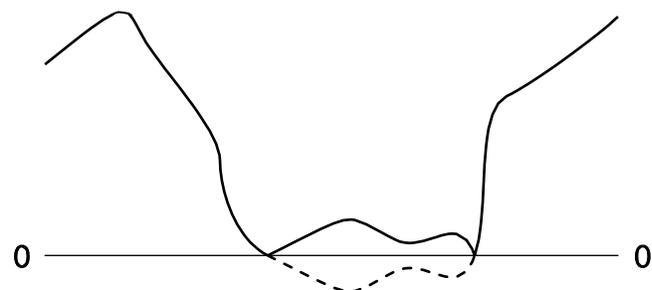
When in the 100% mode, the output reads 10 millivolts per percent, if under 100% (99.0% = 990 mV). When over 100% the output drops a decade to read one millivolt per percent (199% = 199 mV).

### 4.2.2 Auto Ranging Considerations

As briefly mentioned above in section 4.2.1, the chart recorder will automatically stay between 100 to 1000 millivolts. If you are plotting a changing light level, or the output from a spectral scan, the output will abruptly change when either voltage level is reached. It is very obvious from the plot what happened, and what magnitude to place on the data. For example: if the plot is going down and hits the 100 mV lower boundary, the chart recorder will jump to the full scale (1000 mV) position and the plot will continue to come down from that new point of reference. Likewise if it is rising when reaching the 1000 mV boundary, it will drop down to 100 mV and continue on up from that point on. This makes it very convenient for unattended plotting, because you never have to worry about overranging the recorder, or about losing valuable data. If you have an application where you want the chart to go to the traditional zero, you may turn off the auto ranging and the plot will proceed down to zero without autoranging.

### 4.2.3 Negative Readings

Since there is no such thing as negative light, we elected to use a unipolar Digital to Analog (D/A) Converter. This is fine if zero was properly set, and if your ambient conditions do not change throughout the experiment. From our own experiences, we have found that mistakes get made which make the reading occasionally go negative. See the following figure for example:



The data will not get lost since the absolute value of the negative reading will be sent out to the recorder. From the plot it is fairly easy to determine that the reading is negative, since the curve comes back up after it hits zero. If in doubt, it would be wise to rerun the experiment.

#### 4.2.4 Output Impedance

The recorder output impedance is 409 ohms with a 1 microfarad capacitor across it. This gives much less than a 0.1% error when looking into a 1 megohm chart recorder, and gets rid of most radio frequencies. If you want to get rid of all computer generated spikes as well as 60 cycle power noise, we recommend putting a 100 microfarad electrolytic capacitor across the recorder output, preferably located at the chart recorder.

### 4.3 RS232C Output

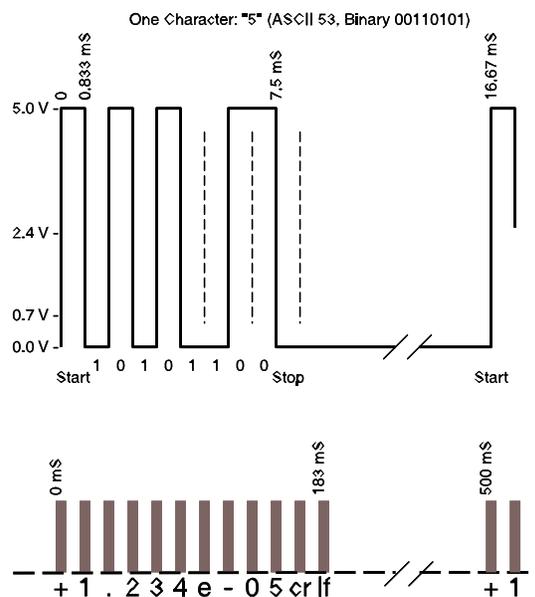
The 25 pin 'D' connector on the rear panel conforms to a subset of the EIA RS-232-C-69 standard dated 9 March 1979 which is available from the Electronic Industries Association, Engineering Department, 2001 Eye Street, N.W., Washington, D.C. 20006. This is a standard for 'Interface between data terminal equipment and data communication equipment employing serial binary data interchange'. The ILT1700 uses pins 1,2,3,4,5,6,7,11, & 20 for one way communication to a receiving digital device with 'hand shaking'. Three (3) wires and a jumper, can be used as a minimum connection configuration, and six (6) wires would be a maximum connection configuration. The following paragraphs will go into more detail on the connection parameters. We offer example computer programs for IBM and compatible systems. Contact an Applications Engineer for assistance.

#### 4.3.1 Baud Rate

The ILT1700 is factory set to an asynchronous baud rate of 1200. Baud rate is the number of bits per second transmitted in each word. In this case there are 10 bits transmitted, so theoretically there could be 120 words per second transmitted using this speed. In actual practice, the computer takes some time in between characters, so the words are sent out with some extra space between words, which is typical for asynchronous transmissions.

#### 4.3.2 Character Format

The ten (10) bits that make up each character word are comprised of one (1) start bit, eight(8) data bits, and at least one(1) stop bit. Since there is a little delay between words, you can count on at least two stop bits to be present in case your system needs that extra time. The following diagram shows the voltage waveform for this serial word.



#### 4.3.3 Voltage Levels & Current Drive

The transmitted data (BA) and the received data (BB) voltage levels are negative logic if we assume a normal digital convention where the 'true' state (logic '1'), is a positive voltage. In other words, in this interface, a 'true' bit (logic '1'), will be negative. This evolved from the old teletype current loop signals, where a 'MARK' was the flow of current out of the terminal, which produced a low voltage for a "1". This same convention has carried on so the negative voltage is a 'MARK' which is considered to be the '1' state, while the 'SPACE' is the positive state, which is a '0' logic level. The rest of the handshaking lines are positive 'true' logic, which conform to the normal convention, where 'true' is positive.

When connected to our RS232C port, the voltage levels will be approximately plus and minus eight (8) volts. This will vary with load, but it more than meets the interface minimums of plus or minus three(3) volts. When designing your receiving interface, it should have an input resistance equal to or greater than 7.5 kilohm and it should be able to switch states at a voltage between +/- 3 volts. In most practical cases, it is desirable to make that decision at a potential slightly above zero volts, which will permit operation on a zero to + 5 volt system, if the need should ever arise. This will also keep the line in the "MARK" state even when in tri-state (open) mode (see below). The higher voltage values were chosen to make long distance transmission possible, due to the increased noise rejection. As mentioned above, our logic levels go into a 'tri-state' mode when not in use, which permits several radiometers to be tied together on the same serial bus. If you try to measure the voltage level when the output is not called, it will read zero (0) volts and appear as an open circuit. A Request To Send (RQS) signal will initiate the sending of data on the next cycle of the radiometer. If RQS is held high, until the first start mark is received, or for at least 300 milliseconds, the ILT1700 will send a data string. If RQS is

held high, the ILT1700 will continue to send data, exactly every 0.5 seconds. Pin 11 provides a compatible voltage (approx. +9 V), that can be used to hold RQS high, if power is not available in your system. Just before transmission, the selected data line (either TRD or RCD), will be pulled down to -8 Volts, to establish the 'MARK' state. The next rising edge, will then be the beginning of the start bit for the first character. A short time after the last character is sent (approx. 10 milliseconds), the bus will automatically revert back to the 'tri-state' condition. See section 4.3.5 for more on this.

#### 4.3.4 Word String Format

The ILT1700 sends out a string of serial words (characters) to transfer the displayed data to other equipment, such as a printer, computer, or modem. There are four different modes of readout: 'auto-range', 'fixed-range', 'percent' and 'factor'. In the first two modes the interface sends out ten (10) to twelve (12) characters with the last being a 'carriage return'. In the percent mode, the port transmits nine (9) characters, with the last being a 'carriage return'. In the first two cases, the extra three (3) or four (4) characters are sent for the exponent including an 'e' to separate the mantissa from the exponent. This makes it very easy for most receiving systems to input the data, using an 'input' statement. If you find difficulty bringing the data string into the computer, you can bring it in as an ASCII text string, then use the letter 'e' along with string manipulation commands to separate the mantissa from the exponent. Since the serial bus is an open circuit when not in use, electrical noise could be picked up on the line before data is transmitted. If this causes a problem, a 47 kilohm resistor can be tied from pin 11 to the active line (either pin 2 or pin 3) to pull the signal up to +11 when no data is being transmitted. To guard against receipt of erroneous information, the string can be interrogated for the nine (9) characters before the carriage return, thus rejecting any bogus transmission from the open line.

#### 4.3.5 Buss sharing (tri-state mode)

As mentioned above, the data line on the RS232C port, is automatically open circuited when not in use. This permits several radiometers, or other sensing devices, to use the same serial buss. Each Radiometer would have a separate RQS (ReQuest to Send) line coming from the central control system (computer), which asks for data. The transmitting device would then 'take over' the line and send a data string, and again go back to a passive state (tri-state mode) after transmission. This is only possible on the RS232C port, not on the TTL serial port.

#### 4.3.6 Gender Selection (DTE or DCE Switch)

There continues to be a great deal of confusion over what connector 'gender' to use, and who is the DTE or DCE. The original interface specification was written for a terminal to be tied to a modem. The terminal was the DTE (Data Terminal Equipment) and the modem was the DCE (Data Communication Equipment). When computers came along, it was unclear as to which category they should fall

into. In many cases, home computers are used as terminals so they were designated as the DTE device. A mainframe computer, on the other hand, may receive the data from remote terminals, so they are taking the place of the DCE. To avoid this problem, we have provided a switch to select either condition. The DTE position is marked 'to computer', and the DCE position is marked 'to printer'. This may not be true for your computer or printer, so just try the other position. The other problem is the gender of the connector. Again, the convention is not clear, so you may have to use a connector adapter that changes a male to a female or vice versa. Cables for each type of hook-up are available from International Light as accessories (see the next section for more details on available cables), or can be purchased from many computer supply stores and distributors.

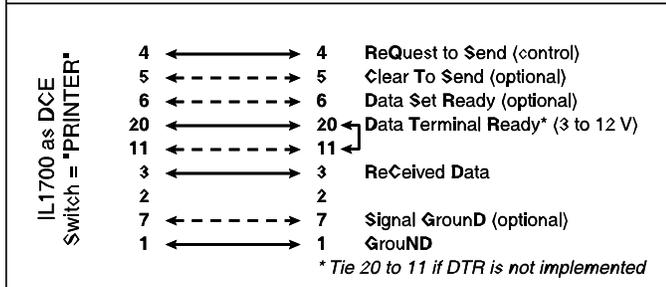
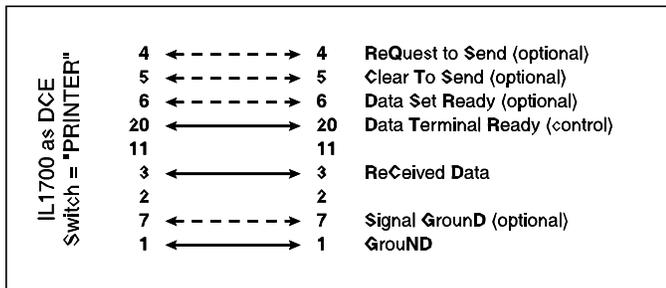
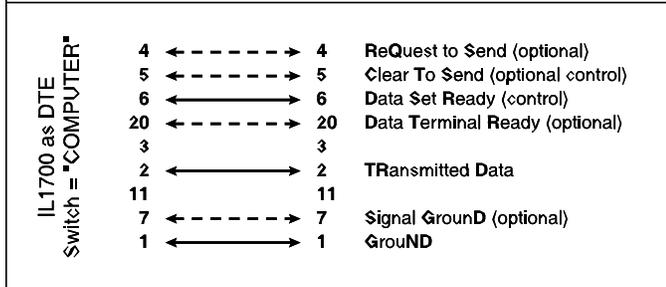
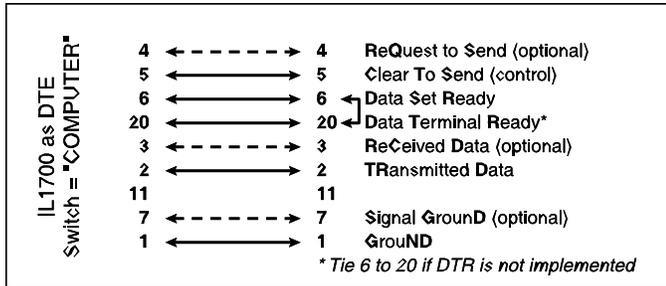
#### 4.3.7 Plug and Cable Requirements

As mentioned in the previous paragraph, there can be some incompatibility because of the 'gender' of the connector on each system. We provide a female 25 pin 'D' connector on the rear of the instrument, so you must have a male to plug into same. We offer two, three (3) meter (10 foot) cables that are male-male (A413), and male-female(A412), to mate to your system. In other words if you have a female connector on your system, you must buy the A413. If you have a male output connector on your system, you need the A412, or your own equivalents.

The following is a chart of the implemented connector pins, as well as the name for each:

Pin Number	RS232C Label	I.L. Label	Description
1	AA	GND	protective GrouND
2	BA	TRD	TRansmitted Data
3	BB	RCD	ReCeived Data
4	CA	RQS	ReQuest to Send
5	CB	CTS	Clear To Send
6	CC	DSR	Data Set Ready
7	AB	SGD	Signal GrouND
11	—	+V	+ 9 Volts
20	CD	DTR	Data Terminal Ready

All of these pins are not active at all times. It depends upon the DTE / DCE switch position. If it is switched to 'printer' (DCE), then pins 1, 3, 4, 5, 6, 7, 11, and 20 are active. If switched 'to computer' (DTE), then pins 1, 2, 4, 5, 6, 7, 11, and 20 are active. Not all pins are necessary at one time. Four wiring configurations are shown in the drawings below, which should help in matching your particular system.



## 4.4 TTL Output

TTL stands for Transistor-Transistor Logic, which is presently the most popular logic level employed in computers. This logic calls the logic '1' any voltage between 2.4 and 5.0 volts, and a logic '0' any voltage between zero and 0.8 volts. It also must have the ability to 'sink' 1.3 milliamps when in the 'zero' state, and source more than 100 microamps when in the 'one' state.

This serial digital output port is found in the upper left hand corner of the rear panel. It is marked 'RECORDER/TTL'. One of the big advantages of the TTL output, is the ability to interface directly with most computer user ports

without buying an expensive hardware adapter. A small machine language program can often make a direct connection possible.

### 4.4.1 Baud Rate

The baud rate is exactly the same as that for the RS232C port, which is 1200 baud. See section 4.3.1 for further explanation.

### 4.4.2 Character Format

The bits of the character word are laid out the same as for the RS232C format. See section 4.3.4 for further reference.

### 4.4.3 Voltage Levels & Current Drive

The output voltage level on pin 5 of the RJ11C jack, is produced by a CMOS peripheral interface adapter chip, which is capable of driving one TTL load. This means that the voltage swing will be the full five (5) volts instead of the typical TTL voltage of +4 volts. The serial word will be in negative logic, meaning that a logic 'one' will be at 0 volts and a logic 'zero' will be at +5 volts. The output line is capable of 'sinking' 1.3 milliamps, and of 'sourcing' much more than 100 microamps, which conforms to the one TTL load requirement. The (inverted) ReQuest to SeND (RQSND) line, on pin 2 of the same jack, will initiate transmission of the data string when pulled to a voltage below 0.8 volts, with either a switch or digital logic level.

### 4.4.4 Word String Format

The serial data sent out on pin 5 is the same as the RS232C format described in section 4.3.4.

### 4.4.5 Plug and Cable Requirements

A standard telephone plug and cable can be used to access the TTL serial data as well as access the recorder output voltage. We have a 7.6 meter (25 foot) cable accessory designated as the A403 for this purpose. The yellow wire is the inverted data line, the black wire is the inverted request to send line, and the green wire is the common ground wire.

# 5. Inputs

## 5.1 Light Sensors

The primary purpose of the ILT1700 is to measure light. For this reason we will address the detection input first. We offer a full line of light detection probes which can generally cover any application area one might have. In a few special cases, the user may want to design his own, or may ask us to make a special probe for his/her application. Consult the factory for assistance in that area.

### 5.1.1 International Light Detectors

Light sensors are generally designed for a band of wavelengths, and for a range of magnitude. The ILT1700 has one of the widest dynamic ranges of any instrument available. It can span 10 decades change in irradiance levels, which is equal to or greater than most detectors. By using attenuators, such as the QNDS-3, the dynamic range is pushed up by a factor of 1000 to handle very intense sources. By using a photomultiplier or high gain lens (L30) the system can be made more sensitive by a factor of 100.

The SED series detectors were also designed to handle hostile environments. The housing is machined aluminum, which forms a rugged case. "O" ring grooves are designed in to offer a sealed option for dirty environments, and for underwater applications. The underwater model (prefixed with SUD) comes with a 30 meter (100 feet) cable and is pressure tested for 40 meter underwater depth.

The most popular detector is the SED033. This is a silicon detector which has a 33 square millimeter receiving surface, and quartz windows to make it usable down to 200 nanometers wavelength. It is specially made to optimize the dynamic range by maximizing the internal shunt resistance, and by minimizing the series resistance, to enhance low level detection and high current linearity, respectively. The large area makes it usable for optical power detection from lasers and fiber optics, as well as to increase its sensitivity for irradiance and illuminance measurements.

Two vacuum photodiodes are also very popular for their ability to exclude infra-red, and for their low noise in D.C. operation. A vacuum photodiode does not have 1/F noise, common with all semiconductors. Also, the leakage current is much lower than semiconductors. The light sensing surface has a lower sensitivity, but by making a larger receiver, the sensitivity is recovered, without excessive leakage current. The 'solar blind' SED240 has the desirable property of rejecting all energy above 320 nanometers (usable band 200-320). This feature offers short wave detection, even in the presence of abundant long wave radiation. A second vacuum photodiode, the SED400, extends the detection from the short wave UV through the UVA band up to the blue-green end of the visible(200-650nm), and yet rejects the infra-red.

For very flat response and long wave detection, we offer the SED623 thermopile detector, which has a built in preamplifier, to transform the tiny light induced voltage

signal into an amplified current compatible with the input of the ILT1700. The dynamic range of a thermopile is limited to 4 decades ( $2e^{-5}$  to  $5e^{-1}$  watts per square cm), but the extremely flat spectral response from 200 to 3000 nanometers, often offsets this range limitation.

If extremely low level detection is necessary we offer three photomultiplier detectors and associated power supply. The PM gain is roughly 500,000 times that of a vacuum photodiode, but the dark noise is also amplified. The net result is to give about 100 times more detectivity for those low level applications. The PM271D has an S-20 spectral response (200-750nm), yet is very rugged for withstanding light overload. Low cost is the feature of our PMD271C with S-5 cathode (200-650 nm). Flat response and extended spectral range is the benefit of our GaAs photomultiplier type PMD271E, at the expense of less sensitivity, and higher cost. We have other specialized detectors available, which will not be covered in this brief review. Please contact the factory for assistance with your requirements.

### 5.1.2 User and Custom Detectors

The detector input port has been designed to be compatible with many types of input devices other than light sensors. Two such transducers are mentioned below in section 5.2 and in previous paragraphs to measure temperature and current. Other devices for measuring humidity, nuclear radiation sound levels, weight, etc., are all possible attachments. The 15 pin 'D' connector has several bias voltages available, as well as the front panel controlled 5 volt bias (see the 1st schematic at the rear of this document for voltage and current ratings of available pins). The system measures negative current (positive electron flow) on pin 6. The return path for the current can be either instrument signal ground (pin 7) or the -9 volt bias available on pin 1. In either case if the front panel bias is selected (5 V BIAS), the input voltage will be raised by 5 additional volts. In other words, if you chose to put the return line to the ground pin 7, the input will rise up to +5 which will reverse bias the input device by 5 volts. This feature also makes it possible to work with photoconductive devices such as cadmium sulfide or cadmium selenide, by measuring the photoconductance. If the -9 Volt bias is the return, and the 5 V BIAS is selected, there will be a net total of 14 volts across the sensor. To minimize leakage current in a coaxial cable, we provide a 'guard' pin called 'bias common', located on pin 9. This always stays at the same potential as the input pin 6, to minimize cable leakage, even if the actual detector is reverse biased. Be careful not to connect this to ground, since this point is elevated to +5 volts when the 5V BIAS button is pressed.

In addition to these sensor related pins, we have made +5 volts and +15 volts available for other specialized preamplification circuitry, and for other accessory probes. No more than 10 milliamps should be drawn from +15, 5 mA from -9, and less than 50 mA from +5.

I will give an example of the hookup for a two wire silicon detector, since that is the most likely device to be used by a customer. The cathode should go to the input pin

6, the anode and the shield of the coaxial cable should be connected to pin 7. With the 5V BIAS off, the detector will operate in the photovoltaic mode. With the 5V BIAS on, the detector would be reverse biased by 5 volts. For more specific assistance with hooking up a special user device, please contact the factory.

## 5.2 Accessories

There are two special accessory probes available to owners of the ILT1700 for using the instrument as a general purpose current measuring device, or for temperature measurements:

### 5.2.1 Current Measurements

By using our A408 accessory input cable, a user can directly measure small currents from  $1e^{-12}$  to  $2e^{-3}$  amperes, as well as measuring conductance from  $2e^{-13}$  to  $4e^{-4}$  Siemens (mhos). The reciprocal of Siemens is ohms if resistance is of interest also.

### 5.2.2 Temperature Probe

Very often it is essential to control all variables when making light measurements. For this reason we offer the A410 temperature probe for making a readout in degrees Celsius, which can be used to monitor the temperature in a test environment over the temperature range of -25 to +105 degrees Celsius.

INSTRUCTIONS FOR A410 USE: 1) Turn on the ILT1700 without anything plugged into the instrument. Switch to factor mode, and then dial in a sensitivity factor of  $1.000e^{-6}$  into one of the 10 factor registers. Switch back to 'DATA' mode, wait 10 seconds, and then press 'ZERO'. 3) Turn the ILT1700 off and plug the A410 Temperature Probe into the input connector of the instrument. 4) Again turn the ILT1700 on and read the temperature directly in degrees Celsius. This readout will be in scientific notation, so be sure to use the exponent. A room temperature test should be about  $2.10e^{+1}$  on the display, which of course is 21 degrees.

# 6. Accessory Input

On the middle right side of the instrument rear panel is the 24 pin card edge connector, marked 'ACCESSORY INPUT'. This connector permits access to circuitry for test purposes, as well as for special user functions. The two most important functions are remote control and auxiliary power, as described below.

## 6.1 Remote Control

Remote operation for continuous wave (D.C) measurements requires only the RS232C port, with the function set to the auto-range mode. Data will be transmitted when requested via the RQS (ReQuest to Send) line on that interface.

Flash measurements require more control over, and coordination with the instrument, through the 'ACCESSORY PORT'. Either external switch control or standard computer logic will activate the four functions equivalent to the front panel push buttons. The (inverted) FLAS output, goes low once the ILT1700 is ready to integrate. This logic level can be used to trigger the flash lamp, or 'handshake' with a computer device to complete a two way protocol. The following is a list of user inputs:

Pin#	Mnemonic	True Level	Description
10	/ZERO	Low	Zero (not)
L	/SWDN	Low	D.C. (not)
J	/INTG	Low	Integrate (not)
K	/HOLD	Low	Hold (not)
9	/FLAS	Low	Flash (not): output

If mechanical activation is required, a switch closure between any of the above listed inputs, with respect to ground, will activate that function. It is only necessary to keep the switch closed for 50 milliseconds to assure sampling response from the internal computer. Contact bounce less than 1 millisecond is allowed for reliable operation.

Digital logic, or the output from a computer user port, can be used if it is TTL compatible or if the drive can 'sink' at least 1 milliamp, to a voltage level below 0.8 volts, and allow the level to rise above 3.5 volts (essentially no sourcing necessary) upon release. The low state is the 'true level' in each case. The description, on the previous chart, shows which function key the low state will equate to.

When the ILT1700 is ready to integrate, it will pull pin 9 to a voltage level less than 0.8 volts (assuming the current load is less than 1.3 mA). This occurs in less than 8 milliseconds after /INTG is pulled low. That line can be used to activate a flash lamp for fully automatic operation.

A fully automatic system would pull '/ZERO' low as part of the initialization routine to cancel out any ambient conditions. Some time later, when a test lamp was in position, '/INTG' would be pulled low for more than 50 milliseconds, or until '/FLASH' was sensed. Three seconds

after that '/HOLD' would be pulled low for 50 mS, and RQS would be sent to the RS232C port until serial data begins to be received. The data would be processed, and a new lamp would be inserted in the test station, and '/SWDN' would be pulled low to zero out the integration register. '/INTG' would be pulled low again to start the next cycle, and so on. The 'AUTO-RANGE' feature should be on to handle any magnitude of light source, and the '5V BIAS' generally should be on to increase the detector speed and to handle the large instantaneous charge from the flash.

## 6.2 Test Pins

There are accessory pins that are used during the system test at the factory, but a user normally will not be concerned with any of these except possibly for pin 11 (VRAM), which tests the 'keep alive' voltage for the continuous memory. This should be greater than 2 volts when measured with a high input impedance volt meter, with respect to ground (found on pins A, or 1). Pin 3 is the +5 volt logic power supply voltage, which can be used for external logic as long as it draws less than 50 milliamps.

## 6.3 Chopper Interface (Future Capability)

The ILT1700 has been designed to permit a future upgrade for synchronous detection using a chopped light source. Pins D,5,E,6,F, and 7 are reserved for that purpose. They are not implemented in the standard ILT1700.

## 6.4 DC Power

When the internal batteries are used, the instrument automatically turns itself off after about 6 minutes. For field testing, continuous measurements may be desired or it may be beneficial to recharge the internal Nickel-Cadmium batteries from a mobile power source. In either case the Auxiliary input can be used as found on pin C. This auxiliary D.C. (direct current) power must have a potential between +8 and +15 volts with respect to the ground pins(A or 1). This range was chosen to permit use of normal mobile power. We offer an accessory called the A401, which provides a cigarette lighter plug, cable, and accessory connector for such mobile use. If mobile power is not available, the instrument may be operated from any 12 volt battery capable of supplying 380 milliamps for the duration of the experiment.

## 6.5 Analog Output

A second analog output pin is available on the accessory connector. It is brought out on pin 8, which uses any of the ground pins 1, A or N, as the signal return path. This signal called RECO is identical to that which is available on the MOD jack described in section 4.2. In other words, you may obtain the recorder output from either of two different outputs.

# 7. Precautions

The ILT1700 has been designed to minimize problems due to improper operation of the instrument. From our 20 years of manufacturing instruments, we have found a few abuses that can cause trouble, as follows:

1) Remove batteries from the instrument if they are not to be used for a long period of time. This is especially true if cheap batteries have been inserted into the battery compartment. We recommend a good quality alkaline battery, that is guaranteed to be leak proof. Better yet, you can buy our rechargeable batteries that have been proven to operate for over 10 years without any damage due to leakage. Also when a nickel cadmium battery goes dead, it does not destroy the life of the battery. In fact it is a good idea to run NiCads down to the low limit on occasion, to prevent a charge 'memory' effect. **DO NOT RECHARGE ALKALINE BATTERIES**, as they will leak, damaging the instrument.

2) If operation is required outside the United States, be sure to check the voltage switch before putting 230 volts into the line cord.

3) Shipping can be a problem if the internal batteries are left inside the instrument. The high 'G' forces associated with a dropped carton, can dislodge a battery that can thereby become destructive to the circuitry inside.

4) Another suggestion regarding shipping. Always pack an instrument well, if it is to be returned for repair or recalibration. We have found damage to circuitry even though the shipping carton shows no obvious abuse on the outside. This happens because a lack of packing forces the instrument to decelerate at such a high rate, that P.C. boards etc. can become dislodged.

5) Be sure to check the zero if you are in doubt about who or when it was last set. The zero level is remembered after the power is turned off. The previous user may have set it to subtract a very high level, which will produce erroneous results for your next measurement.

6) Be careful when measuring UV sources. There are many industrial uses for Ultraviolet light, in UV curing, Photo Resist exposure systems, Printing plate lithography, etc. Proper goggles should be worn that absorb the UV. If in doubt, we offer UV rejecting sun glasses (A26) that are specifically designed to block out all UV.

# 8. Applications

## 8.1 Current and Conductance Measurements

Most light detectors have a linear relationship between the incident irradiance and a current output, as long as the device is biased correctly. For this reason the ILT1700 is a very sophisticated, programmable, current and conductance measuring instrument. Current is measured in the units of Amperes, while conductance is measured in units of Siemens, where a Siemen is the reciprocal of the resistance unit known as the Ohm. There are many other types of transducers that also have an output which is a change of current or conductance. These devices cover measurements in the fields of temperature, pressure, humidity, ionizing radiation, Ph, Voltage, weight, magnetic force, and so on. Since the instrument can be programmed to make the input stimulus read directly in recognized units, it becomes very useful for many other applications above and beyond the measurement of optical radiation.

The ILT1700 has one of the largest dynamic ranges of any instrument on the market. It will read to better than two digit resolution, from  $1e^{-12}$  to  $2e^{-3}$  Amperes and read conductance from  $2e^{-13}$  to  $4e^{-4}$  Siemens (formerly mhos), each of which cover more than nine (9) decades. In addition, it has the ability to integrate these signals from microsecond speeds to 18 years.

### 8.1.1 Polarity

Most light sensitive devices can be configured to produce a negative current (positive electron flow) easier than a positive current. This is especially true of Photomultipliers and vacuum photodiodes. Also, one of the simplest detector configurations uses a detector into an operational amplifier, configured in the transconductance mode, to produce a positive output voltage. For this reason, we have chosen to measure negative current from the sensitive input pin 6 with respect to instrument signal ground (pin 7), or with respect to the input guard voltage (pin 9 called 'bias common'), which stays at the same potential as the input even if you apply the 5V BIAS. In other words, by turning on the 5V BIAS, the input (pin 6) and the guard (pin 9) will rise up to +5 volts, with respect to the instrument ground (pin 7). This input configuration permits front panel bias selection for a two terminal device, using the input and the ground. It also allows for a coaxial shield connection at the input potential, using a three wire configuration. This eliminates the shielded cable leakage current. The 3 wire configuration is necessary for measurements below the nanoamp range.

### 8.1.2 Input Cable

As described above in section 8.1.1, the three pins that are used for current or conductance, are pins 6,7 & 9, which are the input, ground, and input guard (or bias common), respectively. We offer a three (3) meter (10 feet) coaxial input cable (A408), with alligator clips, and matching input

consumement. Since the photo-optically 'weighted' unit of flux is the lumen, we can measure lumens per square meter (lux), lumen per square centimeter (phot), and the lumen per square foot (ft.cd.). Other units of area are possible but are not commonly used. If you have no previous prejudice to one set of units, I would recommend the lux, since the SI units are recognized world wide. The ILT1700 can be used to measure in any of these units just by reprogramming to a new sensitivity factor. To convert from foot candles to lux, just multiply the number of foot-candles by 10.76 for an answer in lux. If you want to convert a foot-candle sensitivity factor to a lux sensitivity factor, just divide the ft.cd factor by 10.76 and dial that new number into the ILT1700 when in factor mode. You can have both factors entered into two different registers, and read in the units required for the particular application.

When making an illuminance measurement, it is necessary to overfill the input aperture. To measure lumens per unit area, the detector must have an area less than that of the beam. This area can be much smaller than those defined in the units being used. Obviously a square meter would be an impractical detector size. The input area doesn't even have to be some particular decimal division of a square meter. This area variable is calibrated into the sensitivity factor as part of the calibration procedure. In general there is a practical size that is small enough to be used in most applications, yet large enough to get a good signal to the detector. If you have an application to measure the uniformity profile of a relatively small spot of light, it would be necessary to reduce the detector input down to a very small hole. This new configuration could be recalibrated by transferring the calibration from the original arrangement to that of the new input structure. The only requirement is a stable light source that is uniform over an area larger than both input configurations. This light is read by the original calibrated detector to determine the Illuminance. The detector is changed to a combination with the small aperture and replaced in the same field of illuminance. The ratio of the original measurement to the new measurement is the factor to multiply the new reading by to get absolute readings. You can also divide the original sensitivity factor by this same ratio to get the new factor with the small aperture. This can be stored in another register for future use.

We previously mentioned the requirement for an eye response spectral sensitivity for Illuminance measurements (obtain "CIE standard observer" data for specifics). In addition to the proper spectral response, the detector must have a proper Lambertian spatial response (Cosine function). See the subsequent section called "SPATIAL RESPONSE", toward the end of this document, for more details on this.

There is another physical parameter that must be considered when making Illuminance measurements, which is the reference plane. Many International Light detectors use a quartz "Wide Eye" diffuser on the front on the detector to create the Lambertian spatial response. This input device establishes the reference plane as the first groove made by the intersection of this diffuser assembly and the next optical

element. This groove is located 6.5 millimeters in from the front of the detector. If the distance to the light source is quite large, the reference distance is not very critical, but if that distance is just a few millimeters, then it becomes very important to place the detector reference at the correct distance. For Teflon and Flashed Opal diffusers, the first surface is the reference distance.

### 8.2.2 Radiometric Irradiance

Irradiance measurements are very much like Illuminance measurements except the spectral response is ideally “flat” over the spectral range of the light source. An exception to this is “Effective Irradiance” which, like the photopic measurement, has a special spectral response function. This function depends on the need of the user. Usually it is designed to match the action spectrum of some chemical reaction, or polymerization process. UV Curing is a good example of an “Effective Irradiance” application. The detector should be designed to match the action spectrum of the photo resist or polymer film, not the light source. In that way the reading will be directly proportional to the optical effect on that substance, and the integral of the “Effective Irradiance”, known as “Effective Energy” or dose, will directly correlate with the amount of curing that took place. Since the ILT1700 is capable of integrating, you can obtain energy readings directly in absolute units, to control exposures for industrial applications and for photo therapy. We stock hundreds of glass and thin film filters to match many different applications. Contact the factory for more specific information on a custom design for your needs.

Lets get back to the classical Irradiance measurement. You would have a “flat” response detector, such as a thermopile, and a light source that is restricted to output within the “flat” region of the detector. Some coatings for thermopiles are “flat” from 200 to 60,000 nanometers, so almost every light source will fall in that “flat” region. So why doesn't everyone use thermopiles? For one thing a thermopile is limited to a low reading of about 20 microwatts per square centimeter, while quantum detectors, such as silicon cells, can be used to measure less than 20 picowatts per square centimeter. The difference is a million to one in sensitivity. For another reason, thermopiles measure everything including the infrared output from your hands and body as well as the room heating radiator, and finally the thermopile measures all regions of the light source, while you may not be interested in the output from most of the emitted spectrum. By the way if you do have a strong optical signal, and want flat response, we offer two thermopiles for the ILT1700. Call the factory for details. For the most part, your application will either need more sensitivity or will require a selected spectral coverage.

After all this talk about spectrum I have not even covered the units of measurement. Flux in the radiometric field is normally measured in optical watts. Occasionally some people use ergs per second, joules/sec., Langley's/minute, E-Viton's, plus quanta flux in microEinsteins. Due to the programmable nature of the ILT1700, we can handle all

these different units. Our sales staff is very knowledgeable in helping you with specific conversions for your application. Fortunately most users prefer watts.

As mentioned for Illuminance, Irradiance is the radiometric parameter for flux density measurement. Therefore we must choose area dimensions to complete the units. Again we are very lucky to have most people agree on the centimeter. When combined together we have watts per square centimeter ( $W/cm^2$ ). The cosine spatial response is also required for Irradiance measurements. See “SPATIAL RESPONSE”, section 8.7, later on in this document.

In addition, the reference distance is defined by the first groove between the diffuser and subsequent optical elements. Exceptions to that would be for applications that use an opal, diffuse white plastic, or Teflon diffuser, in which case the first surface is the reference distance. For some applications that either sense the light directly on the surface of the cell, or on the cell behind a transmissive filter, the reference distance is slightly in front of the cell surface. Each piece of glass that is in front of the actual sensitive surface, moves the reference forward. It requires some sophisticated measurements to accurately define the effective reference plane for each particular combination of elements. In most cases it is not so critical to necessitate that effort, but if the source is less than 100 millimeters, you should precisely define that plane. Consult the factory for help in this endeavor.

For both Illuminance and Irradiance measurements, it is often important to baffle the measurement environment. For example, an open lamp on an optical bench will radiate in all directions. Anyone moving near this lamp, becomes a secondary reflecting source of optical radiation which is sure to change the reading. Baffles and black satin cloth curtains, are very helpful in isolating the experimental area. A hole down the optical axis, should have a sharp edge to avoid reflections from the edge itself. Also square holes are better than round holes, since the edge reflections are less likely to be propagated down an array of multiple baffles. Last, but not least, use plenty of flat black paint. If you are working in the infrared, you might want to get some “3M Black Velvet” which is known to absorb all the way out to 60 microns.

## 8.3 Flux Measurements

We started out discussing flux density measurements, rather than flux alone. Even though this seems backwards, the measurement of flux has many more geometric possibilities, so we are addressing this second.

### 8.3.1 Laser Measurements

You might measure lasers for two reasons. If the final use of the laser is for humans to see, you probably would choose photometric units. An example of this is for laser projection television. On the other hand, the end use may be a ‘point of sale’ scanner which is sensed by a photomultiplier or silicon cell, so radiometric measurements are indicated (see below).

8.3.1.1 Radiometric Laser Power - The optical watt is still the most popular flux measuring unit. This is almost exclusively true for laser applications. Laser flux is often easier to contend with since the beam is like a thread of power, whose position, direction and spectrum are clearly defined and known. Tunable lasers have caused more difficulty in the spectrum determination, but simpler spectral dispersive devices are available to come to that rescue. Here it will be assumed that the user knows the wavelength of the laser, or else a flat response detector and filter combination is used, so the wavelength will make very little error. A detector should be used that has a defined spatial response for both angle and for translational sensitivity. An ideal angle response would be isotropic, which is available by using a large area silicon cell (SED033 or SED100) or our INS250 integrating sphere. They will measure the beam from off axis angles equally. They both also have a uniform sensitivity across the entrance aperture, which eliminates translational errors. When high power sources are used, it is necessary to attenuate the beam. Attenuation inherently occurs with the integrating sphere. Due to expense and size, most people choose a detector with a narrow beam adapter on it, such as the SED038/F/H/N/K15. This is designed to have a cosine spatial response which accepts an off axis angle of +/- 8 degrees with only a 1% error, and translational error of +/- 5 millimeters off axis for another 1% error. It is generally quite easy to keep within these limits, without any special effort. Of course you should try to keep the input beam normal to the detector and on the center line of the detector axis. By the way, distance should not matter when making laser power measurements, as long as the beam underfills the detector input receiving surface. The sensitivity factor that is dialed into the ILT1700 is in Amperes per Watt (A/W) at the laser wavelength. Generally the wavelength should be specified at the time of calibration, or picked from a chart of multi-wavelength calibrations. It is possible to record 10 factors in the ILT1700 for each of 10 different wavelengths. To make an accurate reading, you select the correct factor from registers 0 through 9, and the instrument will read directly in optical watts.

8.3.1.2 Photometric Lumen Flux - Everything applies to photometric laser measurements as it does for radiometric measurements, except that the detector must have a photopic spectral response or a photometric monochromatic calibration, to match the 'CIE standard observer' curve. The photometric flux is measured in lumens. The calibration will therefore be in units of Amperes per lumen (A/lm). The same spatial considerations apply as for the radiometric measurement in the previous section.

### 8.3.2 Wide Beam Flux Measurements

An integrating sphere is the ideal receiver for wide beam measurements, especially if the beams are converging or diverging. Wide beam sources are accurately measured by catching all the light in the beam. The large opening of the integrating sphere input port (which is 37.6mm diameter) makes this an easy task. For diverging beams, it is necessary to be close enough to insure that the outer edge of

the beam is still smaller than the input port diameter. The uniform sensitivity of the port makes it possible to measure the total flux entering the hole. In addition the sphere acts as an attenuator and provides a uniform signal to the detector. Large solid angles can be accommodated. In fact one steradian of flux can be measured by establishing the point source at 34.7 millimeters distance away from the user port. This makes it very easy to make beam candela (lumen/steradian) measurements, since you would be measuring with a solid angle of one steradian. The receiving cone for other solid angles can also be measured with a great deal of accuracy, since the distances are large and uncertainties are minimized. If the distance to the input port is large with respect to the port diameter (37.6mm), then the calculation reduces approximately to the area of the input port (11.10 cm<sup>2</sup>), divided by the distance squared. In other words, if you were 10 centimeters away from the rim of the port, you would divide 11.10 by 100 and get the solid angle to be 0.111 sr.

If the sphere is calibrated to read optical watts, it can still be used to measure irradiance by overfilling the input port. By dividing the number of watts measures, by the input area (11.1 cm<sup>2</sup>), you get the irradiance in watts per square centimeter. If it is calibrated in lumens, then by dividing by the input area in square feet (11.95e<sup>-3</sup>), we will get the number of lumens per square foot which is equal to foot candles.

8.3.2.1 Radiometric (Total Watt Flux) - A sensitivity factor is required for a flat response detector and sphere combination in units of Amperes per Watt (A/W). If a flat response is not available, the calibration must be performed at the wavelength or wave band of interest. The optical radiation must underfill the sphere port hole to be totally quantized in optical power in the beam.

8.3.2.2 Photometric Flux (Lumens) - A sensitivity factor is required for a photopically responsive detector and sphere combination in units of Amperes per Lumen (A/lm). The same spatial conditions apply as in 8.3.2.1 above.

8.3.2.3 Photometric Intensity (mean Spherical Candle Power) - To properly measure the total flux from a source, one must "catch" all the radiation regardless of the emission direction. A sphere is the ideal choice for this application, since you can put the lamp right inside the sphere. Two of the standard intensity measurements would be the candela and the watts/steradian for photometric and radiometric applications respectively. An intensity measurement is the best indication of total efficiency of a lamp, since it indicates its ability to convert electrical power to optical flux.

Isotropic intensity is equivalent to a point source that radiates equally in all directions. This is not physically very practical since most lamps require electrodes and a holder to support the light, which tends to block some of the output radiation. Many lamps produces a close approximation for many applications. A lamp with a reflector behind it would radiate a great deal in one direction, but the same intensity units are often used so this combination can be compared to an isotropic radiator. The units of beam intensity for these

applications, are beam candela (or beam candle power). For this situation, the measurement is best performed with an illuminance meter. Beam intensity is then calculated by multiplying the illuminance by the distance in feet squared, to get this equivalent intensity in one direction. If the output of the source may be used in all directions, then the Mean Spherical Candela (MSC) measurement is better indication of performance. On the other hand, if the output from the source is used in one direction, then beam intensity measurements would be more appropriate. These could be expressed in lumens per steradian (or watts/steradian) in a given orientation, or in units of beam candela as previously mentioned. To make total flux measurements in an integrating sphere requires either a “flat” response or a photopic response, detector sphere combination for the radiometric or photometric measurement respectively. The radiometric calibration would be in units of Amperes per Watt per Steradian, and the photometric calibration would be in either Amperes per Lumen per Steradian, or Amperes per Candela.

## 8.4 Health Hazard Measurements

Any application that measures the effect of light on human beings (or on any chemical process) requires calibration in effective dose units. Light at different wavelengths must be weighted proportional to the effect that each wavelength has on the tissue. The ACGIH (American Conference of Government and Industrial Hygienists) has specifically defined (and recently extended) several hazard bands which are recommended by NIOSH (National Institute of Occupational Safety and Health), namely, the UV Actinic, Blue Hazard, and Erythral bands. The ACGIH Actinic curve exactly weights the hazardous effect of doses at each wavelength in the UVC, UVB, and UVA bands. Using our ACT3 filter to precisely match this function, you can read a direct Threshold Limit Value effective dose measurement, for an EXACT representation of the effective hazardous dosage. Remember, of course, to place the detector at the same nominal reference distance from the source as the typical human subject would be located. For more information on the Actinic Hazard function, we recommend a booklet on Threshold Limit Values by the ACGIH: ISBN # 0-936712-81-3. The telephone number for the ACGIH headquarters is (513) 661-7881. Please contact an Applications Engineer at our manufacturing facility for information concerning dose measurements for health hazard, UV curing and photoresist applications.

## 8.5 Radiance / Luminance Measurements

Our eyes interpret image details over a relatively narrow angle, of approximately 2.5 degrees. This is the zone of the fovea where we analyze an image, as opposed to the entire light sensitive region of the eye. For this reason it has become very important to measure light in a similar fashion to relate to the visual effect. This photometric concept is

called Luminance or brightness, and the radiometric equivalent is called Radiance. In making measurements of Illuminance or Irradiance discussed in 8.2, we find that the magnitude of the measurement will drop off inversely proportional to the square of the distance from a point source to the detector. This is true because the light is being spread out in two dimensions (area), as one backs away from a source, hence the square function. In making luminance or Radiance measurements, we are determining the output from a surface, as a function of flux per solid angle per area. In other words, we are summing up the output from an infinite number of Lambertian emitters over some test surface area. We measure this by looking at the area with a very narrow acceptance angle to intercept a small area inside the uniform sample emitting surface. Changes in the distance do not change the reading, since the area being measured increases directly proportional to the square of the distance, which is in direct opposition to the inverse square attenuation as a function of distance. In other words the two functions cancel to give us a constant reading. This is why luminance is a constant value for a surface, no matter where it is measured. The units for quantizing Luminance are lumens per steradian per square meter (nit), and for Radiance they are watts per steradian per square meter. There also is an old English unit called the foot-lambert (fL), that is still in use. For conversion  $fL \times 3.43 = nits$ . To get the proper acceptance angle you need our Radiance Barrel (R) which has a 2.5 degree field of view, or you must restrict the field of view with a baffled tube. The baffles are extremely important. They remove the reflections from the wall of the tube, letting in only the “line of sight” rays coming through the center of the tube. Be careful that the detector is “looking” at an area, located in the uniform part of the test surface. If you back away from the surface too far, the input angle will eventually be bigger than the test area, and errors will occur.

## 8.6 LED Measurements

Since most L.E.D. applications involve visibility by humans, it is often better to measure the photometric intensity in millicandelas, which more nearly relates to the ability to be seen by a human observer. We have an accessory called ‘LED’ which is specifically designed for this application. It permits the measurement of beam intensity on the optical axis of the L.E.D. source, which is where most of the radiation is concentrated. It provides a holder, custom designed, baffled tube, photometric filter and calibration to read directly in millicandelas with an ILT1700. Consult the factory for more information.

## 8.7 Transmission Measurements

The ILT1700 has been designed to perform the multiplying and dividing necessary to read in percent transmission. By pressing the ‘SET 100%’ button, the present magnitude is normalized to read 100%. Any change in this reading will show the relative percentage to that of

the original number. In addition to the ILT1700 and an appropriate detector, filter, diffuser combination, you will need a light source that is stable over the time interval used for the measurements. Keep in mind that a 1% change in the lamp current often produces a 3% change in the light output. Regulation is therefore important. Also be sure to let your lamp warm up before making measurements. Another important requirement is an aperture and baffles. The aperture is necessary to define the central optical area of the sample filter. An exception to this rule occurs if using a narrow beam from a source such as a laser. The beam defines its own aperture. The next step is to select an optical bandwidth that is of interest. The light source or the receiving detector is filtered to this desired region. Now you are ready to make everything physically stable for the measurements. The full scale reading (100%) is taken through the limiting aperture before the sample is placed behind this aperture. Then the sample is inserted and the attenuation is directly indicated in percent as a digital readout on the ILT1700.

## 8.8 Reflectance Measurements

Reflectance is similar to transmission (see 8.7), with a few more complications. The ultimate use determines if it is important to measure specular reflectance, diffuse reflectance, or both. Most objects around the room are diffuse reflectors, or close approximations. So if the result relates to how well a human can see something, then diffuse would be appropriate. A mirror is a specular reflector designed to bounce the light at an angle that is equal, around the normal to the surface. Many surfaces (such as a coated paper), have a specular component as well as a diffuse component.

### 8.8.1 Specular Reflectance

All reflectance measurements require some special fixtures. In this case you must have a detector holder that can be swept in an angular arc of 90 degrees about a rotational point which has a holder for the flat sample reflector. A stable light source is directed across the top of this rotational point to some distance (x) which hits the properly filtered detector. The button called 'SET 100%' is pressed to establish the unattenuated condition for reference. The reflector is then placed directly over this rotational point, at an angle of 45 degrees to the source. The detector is rotated, also about this same point, for an angle of 90 degrees or until a peak output is found by watching the meter readings. It is important that the distance (x) is still the same as it was before moving the detector. The sample surface must be flat in order to reproduce the same beam divergence as present without any reflector present. There are many variations to this method, depending upon the ultimate use of the reflector. Obviously if the reflector is a curved surface this would not work. It may be necessary to use a setup similar to the diffuse measurement in an integrating sphere, or use a goniophotometer to integrate the output over the entire divergent reflectance angle. These

methods are beyond the scope of this manual however.

### 8.8.2 Diffuse Reflectance

In the previous paragraph, we mentioned two techniques for measuring diffuse reflectance, namely by use of an integrating sphere or by integrating the total reflectance using a goniometer. Both methods require very special equipment, and will be lightly discussed here, since it would be impossible to do the subject justice in a document of this nature. In the first case, a collimated light beam projects through an integrating sphere, out an opposite port on the other side. A detector, with the desired spectral response, is placed in the sphere surface orthogonal to this beam, so as to be blind to either of the other ports. The 'ZERO' button is pressed with the sample port open. Then a white reflectance standard is placed in the sample port, with a surface such as barium sulphate, magnesium oxide etc. and the 'SET 100%' button is pressed. Now the standard is removed, and the sample is replaced in the sample port. The display on the ILT1700 then reads the diffuse reflectance relative to the standard reflectance. If the standard had a reflectance of 98% then you must divide the answer by .98 to get the absolute sample reflectance. This type of measurement does not measure the specular component, since it is reflected back out the beam entrance port and lost. Other angular geometries are required to include the specular component. The application dictates what is to be measured. A goniophotometer is generally very expensive and must be automated to reduce the tedium of taking, and integrating, thousands of data points. The method has been successfully used for total flux and for total reflectance measurements, but at great expense in equipment and man hours. Briefly, it requires a precision mechanical system, that can scan a reflector in at least a hemispherical solid angle. The light given off the reflecting surface is integrated over this entire solid angle, to provide a summation equal to the total reflectance minus a portion where the light enters this hemisphere. That omission can be filled in by interpolating data from either side of the beam entrance zone, for a very accurate integration. The ILT1700 computer interface is ideal for this application since it delivers a reading exactly every half second. If the motion system is driven by stepper motors that can be properly synchronized with the readings, it is possible to perform this entire integration by remote control, in a relatively short period of time.

## 8.9 Spatial Response

Spatial response refers to the change in responsivity as a function of translational displacements (x or y), and with angular displacements (pitch, yaw, and roll).

### 8.9.1 Lambertian Response

Lambertian response is in reference to a particular angular response proportional to the cosine. In other words the cosine of the angle normal to the face of the detector is one or 100%. As the angle goes off axis and becomes parallel to the face of the detector, the reading goes to zero, as does the cosine of the same angle (90 degrees). At 45 degrees the cosine is 0.707, which means that the detector should read the rays with 70.7% of the value produced by the same rays entering normal to the input device.

The reason this spatial response is necessary for accurate measurements is that it matches the spatial response of a perfect absorbing surface. Since Irradiance and Illuminance, are measurements of light falling on a surface, the cosine is compatible with these measurements. An analogy of the perfect absorber might be considered as being a small hole in a piece of sheet metal, placed over a well. All the light that goes in that hole will be absorbed by the deep well hole underneath. None will get reflected back up out of the same hole. If we analyze the effect of a change of angle, such as the sun moving from high noon to sunset, we will see that less light can make it into the hole at sunset, because the effective area of the hole is smaller as you view it from an oblique angle. This reduction in area is directly proportional to the cosine of the angle normal to this surface. On polar plotting paper, the cosine makes a circle, which is convenient when comparing the ideal response with that of an actual plot.

### 8.9.2 Field Baffle

There are times when you should restrict the field of view to delete oblique angles. In a lab environment, you may be working with a light source on an optical bench. The only light of interest is from that source, yet light bounces off the people in the room and back to the detector, creating errors in the readings. This means that you are better off to restrict the field of view if you know there are no sources to be measured, at the oblique angles. This can be done with external baffles, or with our accessory hood (H). Baffles can be made from sheet metal cut to form a sharp edged hole in the middle. A square hole is actually better than a round hole, since it is less likely to create reflections in a multi-baffle array. Also, black velvet is excellent for dividing off test areas from the rest of the rooms lighting. If it is necessary to have light travel down a tube, you can thread the inside of the tube to reduce the wall reflections.

When making luminance or Radiance measurements, it is absolutely necessary to restrict the field of view to one that 'sees' only an intended test area of a reflecting surface, or rear lit surface. Baffles can be used to implement this kind of measurement without resorting to expensive optics.

### 8.9.3 Narrow Angle (Luminance/Radiance)

As just mentioned, there is a requirement for a narrow field of view when making Luminance and Radiance measurements (see section 8.5). This can be accomplished with lenses as in our Radiance barrel (R) accessory. In some applications it is accomplished by using a telescope where

the light is picked up from a small spot in the image plane. This is very nice for measuring the brightness of an illuminated segment of an alpha numeric display, or for measuring the dot brightness on the face of a CRT. Unfortunately these systems are very expensive. Another alternative is to use simple lenses to image a small portion of a test field, onto an aperture which has a detector behind it. This is very effective especially if the source is a repetitive configuration in a production situation. A custom set up can be made to specifically measure that one small emitting surface. Our Radiance accessory has a 2.5 degree field of view, with the objective lens being about one inch in diameter. This is effective as long as the target is larger than one inch. If you must back up from it, the target requirement gets bigger by the distance times  $2 * (\tan 1.25)$ , plus some margin for error. If you were a foot away, the target should be at least 2 inches in diameter.

### 8.9.4 Uniform Receiver Sensitivity

As mentioned in section 8.3, the best receiver for uniformity is the input port of an integrating sphere. The uniformity we now are talking about is that which is measured perpendicular to the optical axis, over the input surface. For Flux measurements it is necessary to have this uniformity, so that small errors in centering the beam do not contribute to much of a change in the measured reading. Our narrow beam adapter (HNK15) attachment, is designed to accept a few millimeters of axial misalignment without appreciable changes in the reading. This is necessary to allow for non critical positioning of laser beam measurements.

## 8.10 Temporal Response

This refers to the light time response. There are many factors that should be considered when measuring fast light pulses, including the need for instantaneous information, or whether dose information is adequate. To obtain instantaneous data, the entire electrical system, including the final oscilloscope, must be properly designed and matched. This includes the connecting cable, characteristic impedances, and matching amplifiers. In most cases it is necessary to put a preamplifier in the detector head to match the high impedance of the detector to the coaxial cable. When you do this, the dynamic range is limited to a few decades at best, and auto ranging is not practical. For these reasons we have chosen to concentrate on dose measuring, which generally matches the ultimate goal of the light pulse, and is compatible with the same detectors used for c.w. measurements. When we say 'ultimate goal', we mean that the energy in a pulse is generally the factor that determines its effectiveness to perform work, and therefore is the best figure of merit when making a measurement. Capacitance is one of the properties of a detector that is very detrimental to fast instantaneous measurements, but does not produce an error when integrating, since it just tends to store the charge for subsequent removal. By designing charge measuring electronics into the instrument, we can rely on charge

storage in both the detector and in a capacitor on the front end of the system. By measuring with a 5 volt reverse bias on the detector, we now eliminate junction saturation due to internal series resistance voltage drop in the detector, plus we store the charge in the capacitance of the detector (approx 4 nanofarads for SED033), the coaxial cable (approx 0.23 nanofarads), and the 390 nanofarad capacitor located on the front end of the amplifier. At 5 volts bias, the system can temporarily store more than 1 microcoulomb of charge, which is quantized in one measurement cycle (half of a second). The lowest charge of 10 picocoulomb, will still have a 5% resolution, providing a pulse dynamic range of five decades. There are other limitations, such as the maximum current output from the detector, and the intrinsic speed of the detector itself which will be covered separately below.

### **8.10.1 Low Duty Cycle (fast pulse)**

As mentioned above, the ILT1700 can measure a single fast pulse as long as the pulse width is generally greater than 5 microsecond, and the peak detector current is less than 20 milliamps. These limitations refer to the SED033 detector, which generally gives the best performance for flash measurements. The vacuum photodiodes are very fast devices, but the peak output current is about 10 microamperes, which is a serious limitation to high speed, high magnitude light sources. If one wishes to measure a continuous stream of pulses, the ILT1700 has a unique capability of averaging the reading, even if the duty cycle is extremely low. This of course is also limited by the boundaries of the peak current, and intrinsic detector speed. Another method for measuring low duty cycle signals, is to integrate while counting the number of flashes. Then divide the total integral by the number of flashes to get the charge in one flash. Still another technique is to integrate for a known period of time, and then divide by the number of seconds to get the average reading. By the way, data is updated exactly every half second. This makes it easy to keep track of time by counting the number of data changes and dividing by 2 to get seconds.

### **8.10.2 High Peak Amplitude**

If you have a very bright c.w. light source that produces more than 2 milliamps from the detector, the instrument will read "HI" on the display. If the peak current is the result of a high amplitude flash, the limit usually is due to the detector saturation. The most often used silicon detector (SED033) can operate up to 20 milliamps before saturation, while the vacuum photodiodes (SED400 or SED240), have a peak less than 10 microamperes. There will not be anything that alerts you to an error, since the problem is in the detector itself. If in doubt, use a 10:1 attenuator to confirm that you still are in a linear region of operation. The output should drop by the same attenuation as that of the filter.

We mentioned current limitations above which may not mean much unless you realize that current can be calculated by multiplying the reading by the sensitivity factor. The product is detector current in amperes.

# 9. General Specifications

## 9.1 Electrical Specifications

### 9.1.1 System Power

The ILT1700 can be powered from both alternating current (AC) as well as direct current (DC). There are three (3) voltage levels for AC, and two (2) for DC explained below.

9.1.1.1 AC Power (100, 115 or 230) - AC Power is plugged into the rear panel connector marked 'POWER INPUT'. A selector switch adjacent to the input receptacle selects either a range from 90 to 130 or the range from 180 to 260. The first position is used for two common voltages of 100 or 115 while the second position is for the nominal 230 volt input.

9.1.1.2 Internal Battery Power (six 'C' cells) - by opening the rear panel (see section 3.1.2) you may insert six 'C' cell batteries. The types may be either Nickel Cadmium rechargeable, or Alkaline. We do not recommend the low cost Zinc Carbon batteries, because of their short life and greater likelihood of leakage. They will work if you must use them in a pinch. We sell the rechargeable batteries as accessory number A404, which have a capacity of 1.8 amp-hours. This is a high capacity battery that will operate the unit for five (5) hours, as opposed to only 3 hours for a standard rechargeable battery available in many electronic and hardware stores. A good quality alkaline battery will operate the unit for over 10 hours with a 2 year shelf life. Since the instrument turns itself off after 6 minutes, this amounts to about 100 measurement sessions in the two year period. If you want to continuously operate the unit on batteries, use the auxiliary power capability below.

9.1.1.3 Auxiliary Power (8.0 - 15 volts D.C.) - External power between +8 and +15 volts D.C can be applied to pin C of the rear panel accessory connector, with respect to ground pin A or 1, at a current consumption below 400 milliamps. A cigarette lighter accessory is available for mobile power (part # A401) or a card edge connector with a hood (A402) is also available to apply auxiliary power.

### 9.1.2 Signal Input (Current)

9.1.2.1 Input Current Range - The ILT1700 can read from  $2e^{-13}$  to  $2e^{-3}$  amperes negative current (positive electron flow) from pin 6 of the 15 pin 'D' connector marked 'INPUT'.

9.1.2.2 Input Shielding - Due to the low levels of current measurement, it is necessary to use a shielded input cable to minimize electrical disturbances. See section 5 for more specific information.

### 9.1.3 Current Measurement Accuracy

9.1.3.1 Display - Full scale accuracy of +/- 0.2% from 1 microamp to 2 milliamp, +/- 0.5% from 1 nanoamp to 1 microamp, and +/- 1% below 1 nanoamp.

9.1.3.2 RS232C - same as for display above.

9.1.3.3 Recorder - plus or minus 1%, +/-4 millivolts.

### 9.1.4 Optical Accuracy

Optical Accuracy is a very difficult entity to address, because it changes with wavelength. The tolerances we mention below are exclusive of NIST uncertainty to absolute, which can vary from less than 1% in the visible to over 6% in the ultraviolet and over 4% in the infrared.

9.1.4.1 Photometric - plus or minus 2% of I.L. working standards (+/- 2% for NBS transfer)

9.1.4.2 Radiometric - plus or minus 3% of I.L. working standards (+/- 3% for NBS transfer)

### 9.1.5 Radio Frequency Interference

9.1.5.1 Output Emissions - This equipment generates and uses radio frequency energy and if not used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a class B computing device in accordance with the specifications in subpart J of part 15 of FCC rules, which are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation.

9.1.5.2 Input Signal Interference - Since the normal measurement range of electrical currents and charges are extremely small, input errors can occur from large sources of radio frequency emission. The input is especially vulnerable to 'pick up' if the input cable is not shielded. All International Light detectors use shielded input cable which is also necessary for any user provided input device.

## 9.2 Size and Weight

### 9.2.1 Size

9 cm High x 22 cm Wide x 24 cm Deep (3.5" x 8.7" x 9.4")

### 9.2.2 Weight

2.3 Kg (5.1 pounds)

## 9.3 Environmental Specifications

### 9.3.1 Operating temperature range

5 to 40 degrees Celsius

### 9.3.2 Storage temperature range

-30 to +60 degrees Celsius

### 9.3.3 Operating and storage relative humidity

0 to 90 %

# 10. Maintenance and Repair

## 10.1 Preventive Maintenance

Since there are no moving parts, except for the push button and slide switches, the biggest problem over a long period of time is corrosion. Remove the batteries if the unit is not to be used for an extended period of time, and store the instrument in its carrying case or suitable plastic bag, with a small amount of silica gel or other desiccant. The optical windows should be cleaned, from time to time, with methyl alcohol or other window cleaning fluid.

## 10.2 Board Replacement

The ILT1700 has been designed so that each of the four (4) printed circuit boards can be exchanged without affecting the calibration accuracy of the system. Two of the boards may be removed by removing the rear panel (see battery replacement procedure). The computer board (middle board), must be removed first. This is accomplished by wiggling from side to side as you pull to the rear. Once it is slightly free, apply an upward force as you pull to the rear, in order to clear the power socket assembly. The amplifier board (top board), can be removed second, by sliding to the rear while wiggling from side to side. The remaining two boards are the power board (bottom board) and the front panel board. It is necessary to remove the top cover to remove either of these two boards. The power board is the third to be removed by taking out three (3) screws that fix the board to the bottom cover. Once the hold down screws are out, the power board will slide to the rear, leaving the front panel with board attached, free to be lifted straight up. Leave the front panel attached to the board for protection of the Liquid Crystal Displays (LCD's).

Reassembly is done in reverse order. Keep in mind that the amplifier board goes in the third (3) slot down from the top, and the computer board goes in the third (3) slot up from the bottom.

The best way to determine which board is defective is by substitution. Most of our representatives can help in this regard. If alternate boards are not available, you must use the schematics to look for a problem. First start with the power board. Measure all the output voltages. Next assemble the power board, front panel board and computer board. Turn the unit off and momentarily short pins 1 and 11 on the rear panel accessory connector, which will reinitialize the memory, then turn the unit on again. You should read  $2.55e^{-10}$  on the display after 5 series of "1's" blink on the display, then all the lights should function normally. If the readings are erratic or completely wrong, the computer board may be at fault. If a single digit or lamp is not functioning, it probably is associated with the front panel board.

Assuming the results so far are ok, now remove the computer board, then insert the amplifier board, and reinsert the computer board in last. If the readings do not change with the input, you probably have a problem with the amplifier board or the detector. To tell which one is at fault, insert a 5.1 megohm 5% resistor into pins 5 and 6 of the input connector. With the same sensitivity factor set in above ( $1.000e^0$ ), and with the '5 VOLT BIAS' light on, you should read  $9.80e^{-7}$  +/- 5% on the display. If not then the problem is most likely in the amplifier board and not the detector. Obviously if it passes all these tests, the problem is with the detector, or you may have an intermittent contact, which cleaned itself in the process of removing the circuit boards. It is wise to rub a pencil eraser across the board contacts before reinserting them back into the unit. Contact corrosion is often a problem with all electronic equipment, especially after many years.

## 10.3 Schematics

Due to the sophisticated nature of this computer control and low level amplification, we do not recommend that the user attempt to make repairs, except by way of board replacement. Specialized equipment is necessary to find the subtle problems that occur with these circuits, and to recalibrate them to original specifications. Schematics are provided, however, to assist in finding certain power voltages and input/output pin numbers etc. and for the unusual situation where no other alternative is available.

## 10.4 Battery Caution

The ILT1700 Radiometer is not able to distinguish between various internal battery types which may be installed. When batteries other than rechargeable NiCad type are installed, the rear panel source switch should never be in the "BATTERY" position while the unit is connected to A.C. power. Battery leakage may result due to overcharging, causing internal damage.

## 10.5 Computer Reinitialization Procedure

The ILT1700 radiometer is a computer operated instrument. The computer chip in the radiometer, not unlike other computer chips, is susceptible to 'lock-up' when unrecognized conditions or signals are received. Some of the typical symptoms of a ILT1700 computer 'lock-up' are as follow:

- LCD display will not change
- One or more of the LED's remain on.
- One or more of the buttons may not work

properly.

If a user experiences any erratic behavior from the ILT1700 a computer 'lock-up' may be the problem. The can be easily reset by the following procedure:

1. Turn ILT1700 Radiometer OFF.

2. Shunt PIN 11 to PIN 1 on accessory input connector for a few seconds (A paper clip or wire works well). The accessory input card connector is on the backpanel of the instrument. Disconnecting the probe is not needed but it makes access to the edge card easier.

3. Turn the unit ON. The LCD display will blink for a few seconds, telling you that the reinitialization is being performed.

4. The calibration factor for your detector should then be re-entered into the instrument..

Please contact the factory if you require further clarification or if this reset procedure does not correct the problem.

## 10.6 ILT1700 Handle Operation

The handle on the ILT1700 is capable of rotating 360 degrees when pulled away from its pivot points. The handle was designed to move easily when pulled from these points. Unnecessary force may cause harm to the handle.

# 11. One Year Warranty

The equipment you have purchased from International Light, Inc. has been expertly designed and was carefully tested and inspected before being shipped. If properly operated in accordance with the instructions furnished, it will provide you with excellent service. The equipment is warranted for a period of twelve (12) months from date of purchase to be free of defects in material or workmanship. This warranty does not apply to damage resulting from accident, alteration, abuse, loss of parts or repair by other than International Light Technologies. The equipment will be repaired or replaced, at our option, without charge to the owner for parts or labor incurred in such repair. This warranty shall not apply unless the equipment is returned for our examination with all transportation charges prepaid to International Light Technologies, 10 Technology Drive, Peabody, MA 01960. International Light Technologies has no other obligation or liability in connection with said equipment.

# 12. Schematics

The following five (5) pages contain electrical schematics to assist in repair of the instrument.

## 12.1 Photo Sensitive Device Wiring

## 12.2 ILT1700 Amplifier Diagram

## 12.3 ILT1700 Front Panel Schematic

## 12.4 ILT1700 Computer and I/O Schematic

## 12.5 ILT1700 Computer & I/O Schematic (cont'd)

## 12.6 ILT1700 Power