EME Systems

Universal Transconductance Amplifier

Universal Voltage Output Amplifier for LI-COR™ Sensors

(Amplifies LI-COR sensor current to voltage-logger level) Version 2A

User Manual

Contents:

Tables, Figures and Equations:

rev 2a.20071204

This page intentionally left blank

Universal Voltage Output Amplifier for LI-COR™ Sensors

(Amplifies LI-COR sensor current to voltage-logger level)   Version 2A

The following instructions are provided to assist you in the installation and operation of your amplifier. While we have made every effort to protect the amplifier from faults, improper installation or misuse may result in incorrect readings, or at worst, failure of the amplifier. Please read the manual in its entirety before connecting power to the UTA. If you have questions about the UTA or any portion of this manual, please contact EME Systems technical support:
e-mail : support@emesystems.com
phone: (510) 848-5725, between the hours of 10:00 AM to 5:00 PM PST
fax: (510) 848-5748.

Overview and specifications:

The UTA is a special purpose amplifier that converts the microamp-level current output of LI-COR[1] light sensors to a corresponding signal voltage, and provides a simple interface between LI-COR sensors and voltage input data loggers, chart recorders, HVAC, and greenhouse controls. The UTA can be configured at EME Systems or by the end user for any one of a large number of gain settings, through manipulation of two switch blocks.   The calibration tag provided by LI-COR™ with each sensor, in conjunction with the preset amplifier gain factor, can be used to compute the light levels incident on the sensor with a high degree of accuracy.

Typical settings:

LI-COR sensor	**Typical full sun response**	**UTA output (user selectable)**
LI-190, 191, 192, 193 PAR sensors	14 µA @ 2000 µE/m²s	1, 2, 5, 10 Volts out @ 16.67µA input
LI-200 Pyranometer	100µA @ 1000 W/m²	1, 2, 5, 10 Volts out @ 125µA input
LI-210 Photometer	40µA @ 100 klux (=9290 ftcd)	1, 2, 5, 10 Volts out @ 50µA input

These settings correspond to those of an earlier version of our UTA amplifier, and are still our “standard” settings.   Many alternate gain settings are available from the table on page 6 & 8. Those are useful for different full scale ranges of equipment or for sensors under special lighting conditions. Higher gain settings are useful for low light levels, typical of photometers indoors or PAR deep underwater. A special UTA-HOBO is available for use with ONSET HOBO[2] data loggers (appendix A).

Specifications (standard configuration):

- Supply Voltage: 5–24 VDC, single supply, at least 1 volt higher than full scale out
  (Special versions are available that have different power requirements)
- Supply Current: less than 1mA
- Gain accuracy:± 0.2% on factory preset range (± 0.5% all ranges)
- Voltage output in darkness: <4 millivolts
- Supply Voltage variation effect: less than 0.01% per Volt
- Response: 2 milliseconds (special versions available)
- Operating Temperature: -30°C to +70°C
- Tempco: less than 0.01% per °C
- Output impedance: 1000Ω ±1%
- NEMA 4 gasketed white polycarbonate (also available without)
  enclosure: 1.37“ x 1.96” x 2.55“ (4.15” w/glands)
  PG7 gland nut or BNC at input, PG7 gland nut at output
- RoHS compliant, lead free
- Phoenix® beryllium/copper i/o terminals.

Ordering example: UTA/200/5   standard UTA configured for LI200 and 5 volts full scale output
UTA/BNC/gx=0.56   UTA with BNC input connector, gain set at 0.56 volts per microamp.

[1] LI-190, LI-191, LI-192, LI-193, LI-200,LI-210 and part designations are trademarks and the exclusive property of LI-COR Biosciences, Lincoln, Nebraska (www.licor.com)

[2] HOBO is a trademark of ONSET Computer Corporation, Bourne, MA., U.S.A. (www.onsetcomp.com)

Connect the input and output

The first step in using the UTA is to configure it for the LI-COR sensor and output voltage scaling you wish to use. You may have ordered your UTA pre-configured for the appropriate sensor and full scale output voltage you need. The preset value is marked on a label outside the UTA enclosure. If you need to set or reset the gain factor, please refer to pages 4–8, “Configure the amplifier gain switches”.

1) UTA amplifiers are enclosed in a protective enclosure. To gain access to the connection terminals and switch blocks, remove the two corner screws using a standard screwdriver and lift up on the top. There is a connection diagram under the cover.

2) Refer to figure 1. The UTA has connections for the LI-COR sensor input at one end of the circuit board and for the power supply and signal output at the other end.

a) LIXXX-**SZ** (bare wire termination): LI-COR part numbers ending with “SZ” are terminated with a stripped and tinned bare coaxial cable. The LI-COR cable may need to be enlarged in diameter to make a snug fit in the cable gland. Use heat shrink or silicone tubing for this purpose. On the inside of the box, connect the inner conductor (white, or clear) to the white colored terminal on the UTA board and connect the outer wire (shield or tinned copper wire) to the neighboring black terminal.

or

LIXXX-**SA** (BNC termination): LI-COR part numbers ending with a “SA” are terminated with a BNC connector and should be used with the UTA-BNC amplifier. Simply align the connector with its mate on the outside of the UTA-BNC and twist the two halves together. The BNC connectors should lock together when they are properly seated.

b) Connect the power supply from your data logger between the black (common) and red (+ DC voltage) terminals in the group of three. The power supply voltage must be at least 5 volts, and must be greater than the full-scale output volt-

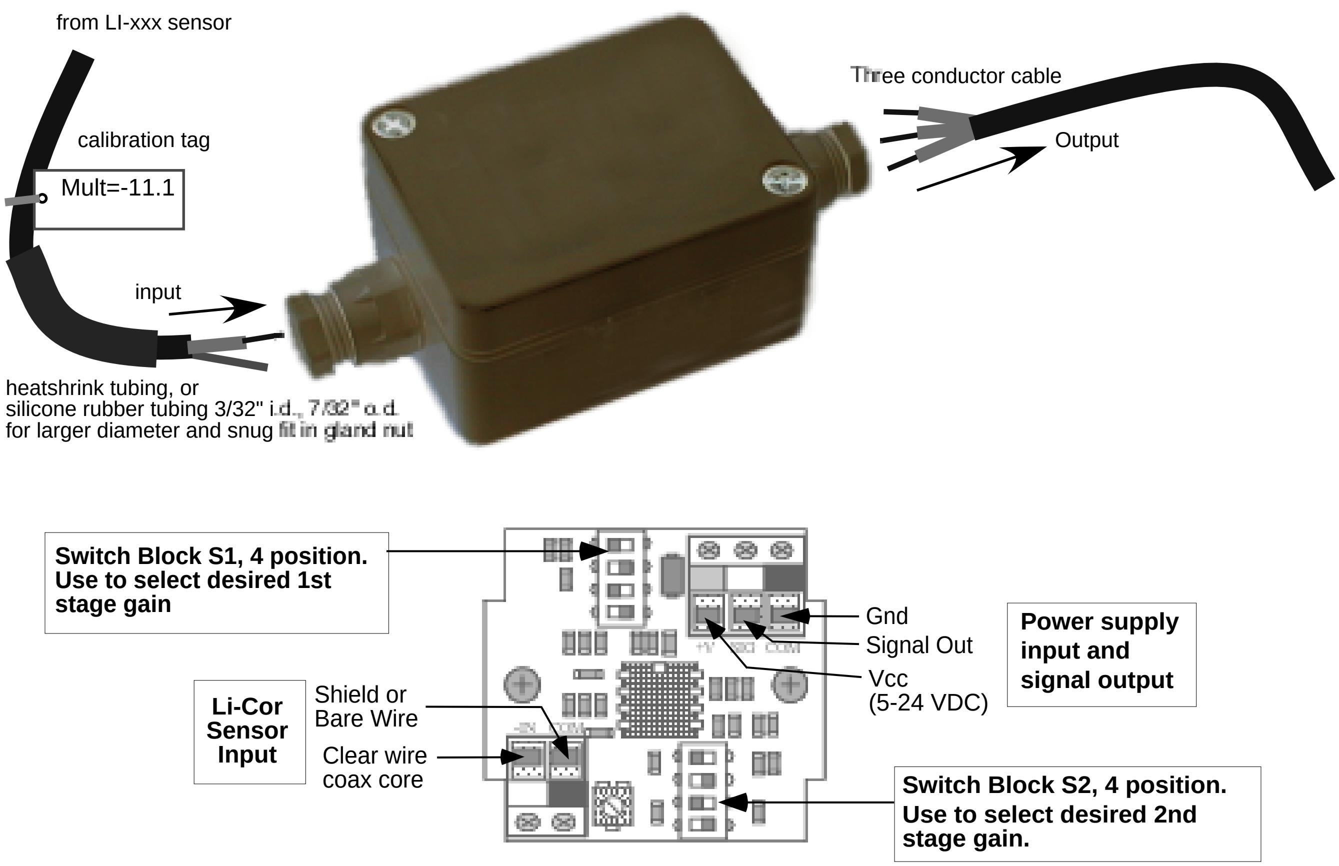

Figure 1: UTA switch and connections diagram

age you select for the UTA (e.g., if using the 10.0 V F.S setting, your power supply must provide at least 11 volts, or it must provide 6 volts power for 5 volt output, or 5 volts power for a 1 to 4 volt output.) The UTA uses a dual operational amplifier integrated circuit that is capable of low offset voltage and operation on power supplies up to 28 volts. For special gain settings, we may employ a special op-amp that has even lower offsets, but will only operate from lower supply voltages. If that is the case, it will be noted on the amplifier calibration tag. The UTA draws less than 1mA of current, making a battery a viable option for a power supply.

c) The signal from the UTA should be taken between the green and black terminals. Green is signal and black is common. The green terminal should be connected to the signal input of your logger and the black terminal should be connected to common. Note that the black terminal is common to both the power supply and signal line.

3) Check all connections for proper polarity and be sure all wires are clamped solidly in place. Replace the top cover on the enclosure and tighten the corner screws. Take care not to over tighten the cover screws as this may cause the cover to deform or "saddle" which can compromise the seal.

Notes:
• Noise sources: For long runs in the presence of halide lamps or other noise sources, you should consider using shielded, three-wire cable for the power and signal connections between the logger and the UTA, with the shield tied to common at one end only.
• Long wire runs: The LI-COR sensors come with 10 feet or 50 feet of cable. The rest of the wire run from the UTA to the data logger or controller should be made with #22 gage or heavier wire. The current flowing in the ground lead creates an error voltage that is added to the apparent output signal. For example, 1000 feet of 22 gage wire has a resistance of approximately 15 ohms. The UTA power supply current of 0.0005 amp flowing in that wire would create a 7.5 millivolt offset. On the 5 volt scale, the error would be 0.0075/5 * 100 = 0.15%. It is unlikely that you will be using such long wire runs. However, poor connections in the ground lead can provoke similar errors. Be sure the ground lead is well secured. The UCLC amplifier, also offered by EME Systems, is better suited to transmission of data as a current over long distances.

Calculate the light level:

In order to convert the UTA's output voltage into the appropriate units of light, you will have to program your equipment to multiply the UTA output voltage times the LI-COR calibration multiplier and divide by the UTA's transconductance gain (volts per µAmp)

$$\textbf{Light Level} = \frac{\textbf{(UTA output volts) * (sensor multiplier)}}{\textbf{(UTA transconductance gain)}} \qquad \textit{(Equation 1)}$$

Each individual LI-COR sensor has a distinct calibration multiplier. You can find the multiplier for your particular sensor on the calibration tag on the cable of your LI-COR sensor, or the calibration certificate that came along with the sensor. Drop the minus sign from the multiplier when carrying out the conversion calculation.

The gain factor for each UTA as shipped from EME Systems is printed on a calibration tag on the side of its enclosure. Please refer to Table 2 to find the UTA transconductance gain for standard UTA output settings. **NOTE:** If you ordered a UTA–HOBO, please refer to the appendix section entitled "**Calculating light level from the UTA–HOBO**" for conversion calculations.

Table 1: standard output, (**transconductance gain in volts per microamp, and switch setting**)

Version 2A		Standard full scale output voltage			
		1 volt fs	2 volts fs	5 volts fs	10 volts fs
LI-COR sensor	LI-190 series Quantum PAR	0.06 V/µA S1=6, S2=15	0.12 V/µA S1=6, S2=14	0.3 V/µA S1=6, S2=11	0.6 V/µA S1=6, S2=7
	LI-200 Pyranometer	0.008 V/µA S1=13, S2=15	0.016 V/µA S1=13, S2=14	0.04 V/µA S1=13, S2=11	0.08 V/µA S1=13, S2=7
	LI-210 Photometer	0.02 V/µA S1=10, S2=15	0.04 V/µA S1=10, S2=14	0.1 V/µA S1=10, S2=11	0.2 V/µA S1=10, S2=7

Example calculations:

Example 1: UTA/190/1, amplify LI-190 PAR sensor output up to level of 0–1 volt full scale.

- UTA gain (1st column, 1st row in **Table 1**): 0.06 V/µA (1 Volt full-scale at 16.67 µA input from LI-190)
- multiplier, from LI-190 Quantum PAR sensor calibration tag or certificate: -148.50 µE/m^{2}s per µA (hypothetical).
- volts reading: 0.836 Volts (hypothetical)

==> light level = UTA volts * [148.50 / 0.06] = (0.836 volt) * (2475 µE/m^{2}s per volt) = **2069 µE/m^{2}s**

Example 2: UTA/200/5, Amplify pyranometer output to 5 volts full scale.

- UTA gain (3rd column, 2nd row in **Table 1**): 0.04 V/µA (5 Volts full-scale at 125 µA input from LI-200)
- multiplier, from LI-200 Pyranometer sensor calibration tag or certificate: -9.80 W/m^2 per µA (hypothetical)
- volts reading: 3.80 Volts (hypothetical)

==> light level = UTA volts * [9.80 / 0.04] = (3.80 volts) * (245.0 W/m^2 per volt) = **931 W/m^2**

Example 3: UTA/210/10, Amplify photometer output to 10 volts full scale (sunlight)

- UTA gain (4th column, 3rd row in **Table 1**): 0.2 V/µA (10 Volts full-scale at 50 µA input from LI-210)
- multiplier, from LI-210 Photometer calibration tag or certificate: -2.63 klux/µA (hypothetical)
- volts reading: 6.25 Volts (hypothetical)

==> light level = UTA volts * [2.63 / 0.2] = (6.25 volts) * (13.15 klux per volt) = **82.2 klux**.
If you need units in footcandles, 1 footcandle=10.764 lux.

Notes:
1) If you need a different calibration setting, please refer to the next section or contact EME Systems. For example, this would be called for if you need a different full scale voltage, or if you are measuring a low light level.
2)Note that LI-190, LI-191, LI-192, and LI-193 sensors all use roughly the same UTA transconductance gains. The LI-192 and LI-193 have different calibration multipliers underwater and above water.

Configure the amplifier gain switches:

Most UTA users select from the standard 1, 2, 5, or 10 volt output settings. However, the UTA can be ordered or set by the end user to a gain setting to fit a particular requirement. The gain settings that can be had through the switch settings are shown in table 2, and the manner of setting the switches in figures 2 and 3.

Find the transconductance gain necessary for your application using the following equation:

$$\textbf{UTA transconductance gain} = \frac{\textbf{(desired UTA full scale output volts)}}{\textbf{expected UTA input current from light sensor at full scale}} \qquad \textit{(Equation 2)}$$

Once the transconductance gain has been calculated, use Table 2 and Figure 3 to find a switch configuration that sets the actual UTA gain close to the calculated gain. Insert the transconductance gain found in Table 2 into equation 1 to calculate the actual light level detected by your sensor.

Examples of custom UTA gain settings:

• Say you are working with a photometer in moderate light level conditions indoors where you expect to see top light levels around 10 klux. Standard UTA gain settings will not sufficiently amplify such low light levels at a good resolution. You have a photometer with a calibration multiplier of 2.78 klux per µA. The controller you are using has analog input channels that allow 0-5 volts. Using equation 2, the necessary transconductance gain is:
(5V)*(2.78 klux/µA) / 10 klux = 1.39 V/µA
Looking at Table 2, we find that switch 1: index 2, switch 2: index 7 provides a transconductance gain of 1.400 V/µA, which is close to the calculated gain. Configure the switches to the correct positions, then use equation 1 to calculate the actual light level from the observed UTA voltage output:
Light Level = UTA volts * (sensor multiplier / UTA transconductance gain *from Table 2*)
Light Level = UTA volts * (2.78 klux per µA / 1.400 Volts per µA)

• Say you are working with a quantum PAR sensor in a greenhouse with high intensity lighting where measured PAR can achieve levels of 2500 $\mu E/m^2s$. Standard UTA gain settings could saturate at such high light levels. You have a quantum PAR sensor with a calibration multiplier of 138.31 $\mu E/m^2s$ per μA. Your controller has analog input channels that allow 0-1 volt. Using equation 2, the necessary transconductance gain is:

$(1V)*(138.31\ \mu E/m^2s \text{ per } \mu A) / (2500\ \mu E/m^2s) = 0.0553\ V/\mu A$

Looking at Table 2, we find that switch 1: index 8, switch 2: index 14 provides a transconductance gain of 0.056, which is close to the calculated gain. Configure the switches to the correct positions, then use equation 1 to figure out the actual light level from the observed UTA voltage out:

Light Level = UTA volts * (sensor multiplier / UTA transconductance gain *from Table 3*)

Light Level = UTA volts * (138.31 $\mu E/m^2s$ per μA / 0.056 Volts per μA)

Notes:

• Choose a full scale output voltage less than or equal to your logger's input capability -but not too much less. For example, if your logger has a full scale input range of 2.5 volts, you should choose a setting that will never exceed 2.5 volts, but will come close to that at its maximum.
• If you select too low a setting, you will lose resolution and your logger will not register subtle changes and may fail to register the lowest light levels of interest.
• If you select too high a setting, the amplifier may overdrive or saturate the input circuit on your meter or even damage its inputs. The highest light levels will all register as one value: off scale!
• You may wish to purposely select a higher output setting to achieve greater sensitivity at low light levels. This might be useful in studies of indoor lighting, or deep water studies with the LI192 or LI193, where full-sun intensities will never be attained.
• The UTA power supply must always be greater than or equal to the full scale output voltage.
• You can use alcohol to rub off the old mark on the calibration label, and a Sharpie™ marker for the new one.

Table 2: Switch positions as a function of gain required. Note that some of the gain settings can be achieved with multiple switch combinations. When this is the case, it is usually preferable to choose a high gain (low switch position) in the first amplifier stage, S1.

<table>
<tr><th>Gain (V/µA)</th><th>Possible Switch Setting Combinations (S1, S2)</th></tr>
<tr><td>0.004</td><td>14,15</td></tr>
<tr><td>0.008</td><td>13,15 | 14,14</td></tr>
<tr><td>0.012</td><td>12,15 | 14,13</td></tr>
<tr><td>0.016</td><td>11,15 | 13,14 | 14,12</td></tr>
<tr><td>0.02</td><td>10,15 | 14,11</td></tr>
<tr><td>0.024</td><td>9,15 | 12,14 | 13,13 | 14,10</td></tr>
<tr><td>0.028</td><td>8,15 | 14,9</td></tr>
<tr><td>0.032</td><td>11,14 | 13,12 | 14,8</td></tr>
<tr><td>0.036</td><td>12,13</td></tr>
<tr><td>0.04</td><td>7,15 | 10,14 | 13,11 | 14,11</td></tr>
<tr><td>0.048</td><td>9,14 | 11,13 | 12,12 | 13,10</td></tr>
<tr><td>0.056</td><td>8,14 | 13,9</td></tr>
<tr><td>0.06</td><td>6,15 | 10,13 | 12,11 | 14,6</td></tr>
<tr><td>0.064</td><td>11,12 | 13,8</td></tr>
<tr><td>0.072</td><td>9,13 | 12,10</td></tr>
<tr><td>0.08</td><td>5,15 | 7,14 | 10,12 | 11,11 | 13,7 | 14,5</td></tr>
<tr><td>0.084</td><td>8,13 | 12,9</td></tr>
<tr><td>0.096</td><td>9,12 | 11,10 | 12,8</td></tr>
<tr><td>0.1</td><td>4,15 | 10,11 | 14,4</td></tr>
<tr><td>0.112</td><td>8,12 | 11,9</td></tr>
<tr><td>0.12</td><td>3,15 | 6,14 | 7,13 | 9,11 | 10,10 | 12,7 | 13,6 | 14,3</td></tr>
<tr><td>0.128</td><td>11,8</td></tr>
<tr><td>0.14</td><td>2,15 | 8,11 | 10,9 | 14,2</td></tr>
<tr><td>0.144</td><td>9,10</td></tr>
<tr><td>0.16</td><td>1,15 | 5,14| 7,12 | 10,8 | 11,7 | 13,5 | 14,1</td></tr>
<tr><td>0.168</td><td>8,10 | 9,9</td></tr>
<tr><td>0.18</td><td>0,15 | 6,13 | 12,6 | 14,0</td></tr>
<tr><td>0.192</td><td>9,8</td></tr>
<tr><td>0.196</td><td>8,9</td></tr>
<tr><td>0.2</td><td>4,14 | 7,11 | 10,7 | 13,4</td></tr>
<tr><td>0.224</td><td>8,8</td></tr>
<tr><td>0.24</td><td>3,14 | 5,13 | 6,12 | 7,10 | 9,7 | 11,6 | 12,5 | 13,3</td></tr>
<tr><td>0.28</td><td>2,14 | 7,9 | 8,7 | 13,2</td></tr>
<tr><td>0.3</td><td>4,13 | 6,11 | 10,6 | 12,4</td></tr>
<tr><td>0.32</td><td>1,14 | 5,12 | 7,8 | 11,5</td></tr>
<tr><td>0.36</td><td>0,14 | 3,13 | 6,10 | 9,6</td></tr>
<tr><td>0.4</td><td>4,12 | 5,11 | 7,7 | 10,5 | 11,4</td></tr>
<tr><td>0.42</td><td>2,13 | 6,9 | 8,6 | 12,2</td></tr>
<tr><td>0.48</td><td>1,13 | 3,12 | 5,10 | 6,8 | 9,5 | 11,3 | 12,1</td></tr>
<tr><td>0.5</td><td>4,11 | 10,4</td></tr>
<tr><td>0.54</td><td>0,13 | 12,0</td></tr>
<tr><td>0.56</td><td>2,12 | 5,9 | 8,5 | 11,2</td></tr>
</table>

<table>
<tr><th>Gain (V/µA)</th><th>Possible Switch Setting Combinations (S1, S2)</th></tr>
<tr><td>0.6</td><td>3,11 | 4,10 | 6,7 | 7,6 | 9,4 | 10,3</td></tr>
<tr><td>0.64</td><td>1,12 | 5,8 | 11,1</td></tr>
<tr><td>0.7</td><td>2,11 | 4,9 | 8,4 | 10,2</td></tr>
<tr><td>0.72</td><td>0,12 | 3,10 | 9,3 | 11,0</td></tr>
<tr><td>0.8</td><td>1,11 | 4,8 | 5,7 | 7,5 | 10,1</td></tr>
<tr><td>0.84</td><td>2,10 | 3,9 | 8,3 | 9,2</td></tr>
<tr><td>0.9</td><td>0,11 | 6,6 | 10,0</td></tr>
<tr><td>0.96</td><td>1,10 | 3,8 | 9,1</td></tr>
<tr><td>0.98</td><td>2,9 | 8,2</td></tr>
<tr><td>1</td><td>4,7 | 7,4</td></tr>
<tr><td>1.08</td><td>0,10 | 9,0</td></tr>
<tr><td>1.12</td><td>1,9 | 2,8 | 8,1</td></tr>
<tr><td>1.2</td><td>3,7 | 5,6 | 6,5 | 7,3</td></tr>
<tr><td>1.26</td><td>0,9 | 8,0</td></tr>
<tr><td>1.28</td><td>1,8</td></tr>
<tr><td>1.4</td><td>2,7 | 7,2</td></tr>
<tr><td>1.44</td><td>0,8</td></tr>
<tr><td>1.5</td><td>4,6 | 6,4</td></tr>
<tr><td>1.6</td><td>1,7 | 5,5 | 7,1</td></tr>
<tr><td>1.8</td><td>0,7 | 3,6 | 6,3 | 7,0</td></tr>
<tr><td>2</td><td>4,5 | 5,4</td></tr>
<tr><td>2.1</td><td>2,6 | 6,2</td></tr>
<tr><td>2.4</td><td>1,6 | 3,5 | 6,1 | 5,3</td></tr>
<tr><td>2.5</td><td>4,4</td></tr>
<tr><td>2.7</td><td>0,6 | 6,0</td></tr>
<tr><td>2.8</td><td>2,5 | 5,2</td></tr>
<tr><td>3</td><td>3,4 | 4,3</td></tr>
<tr><td>3.2</td><td>1,5 | 5,1</td></tr>
<tr><td>3.5</td><td>2,4 | 4,2</td></tr>
<tr><td>3.6</td><td>0,5 | 3,3 | 5,0</td></tr>
<tr><td>4</td><td>1,4 | 4,1</td></tr>
<tr><td>4.2</td><td>2,3 | 3,2</td></tr>
<tr><td>4.5</td><td>0,4 | 4,0</td></tr>
<tr><td>4.8</td><td>1,3 | 3,1</td></tr>
<tr><td>4.9</td><td>2,2</td></tr>
<tr><td>5.4</td><td>0,3 | 3,0</td></tr>
<tr><td>5.6</td><td>1,2 | 2,1</td></tr>
<tr><td>6.3</td><td>0,2 | 2,0</td></tr>
<tr><td>6.4</td><td>1,1</td></tr>
<tr><td>7.2</td><td>0,1 | 1,0</td></tr>
<tr><td>8.1</td><td>0,0</td></tr>
</table>

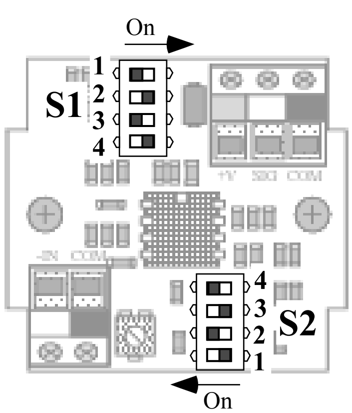

Figure 2: Location of Switch 1 (S1) and Switch 2 (S2) on the UTA circuit board. See Figure 3 for switch setting information.

Figure 3a: Settings for Switch 1 (S1)

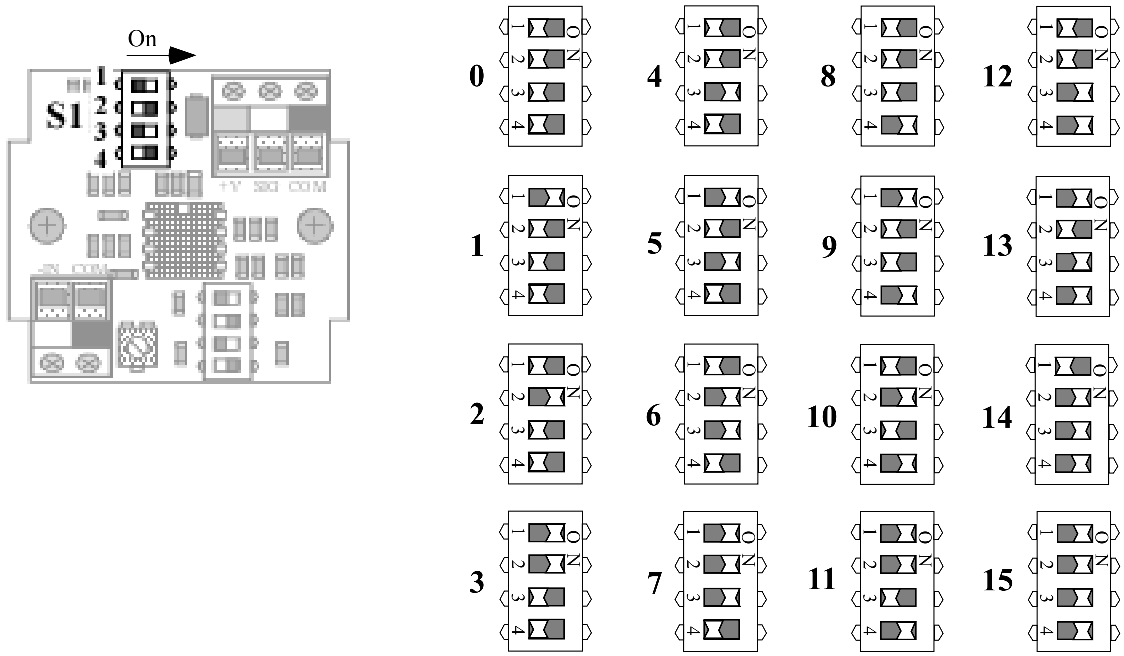

Figure 3b: Settings for Switch 2 (S2)

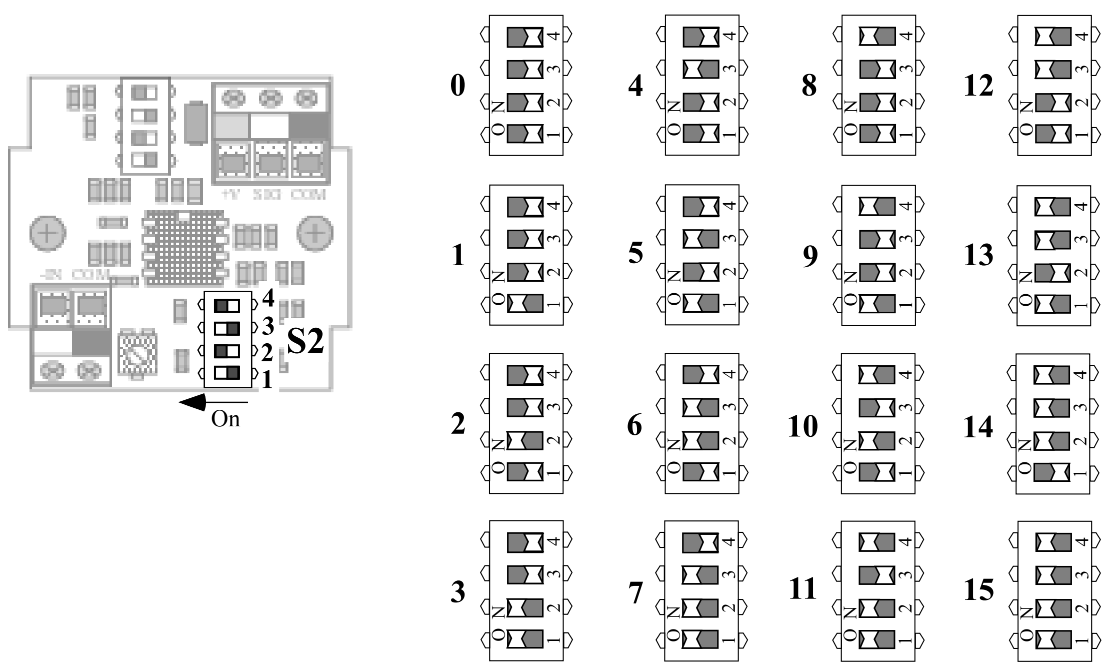

Figure 3: Settings for Switch 1 (S1) and Switch 2 (S2). Use combinations of S1 and S2 settings as described in Table 2 to set desired gain of UTA.

Table 3 : Gain as a function of switch position.
Body of table: Overall UTA gains expressed as volts per microamp. range from 0.004 volts/µA to 8.1 volts/A.
Left and top: DIP switch positions for first and second amplifier state, 0=switch off, 1=switch on
note that gain increases as switch position number decreases.
Left side: switch position for the first amplifier stage,
from switch position 1110, giving gain 0.004 volts/µA
to switch position 0000, giving gain=0.18 volts/µA.
Top side: switch positions for second amplifier stage,
from switch position 1111, giving gain = 1 volts/volt
to switch position 0000, giving gain = 45 volts/volt

switch 1 positions	binary	switch 2 positions →	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		binary	1111	1110	1101	1100	1011	1010	1001	1000	0111	0110	0101	0100	0011	0010	0001	0000
		2nd stage gain volts/volt / 1st stage gain, volts/µA	1	2	3	4	5	6	7	8	10	15	20	25	30	35	40	45
14	1110	0.004	0.004	0.008	0.012	0.016	0.020	0.024	0.028	0.032	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180
13	1101	0.008	0.008	0.016	0.024	0.032	0.040	0.048	0.056	0.064	0.080	0.120	0.160	0.200	0.240	0.280	0.320	0.360
12	1100	0.012	0.012	0.024	0.036	0.048	0.060	0.072	0.084	0.096	0.120	0.180	0.240	0.300	0.360	0.420	0.480	0.540
11	1011	0.016	0.016	0.032	0.048	0.064	0.080	0.096	0.112	0.128	0.160	0.240	0.320	0.400	0.480	0.560	0.640	0.720
10	1010	0.020	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
9	1001	0.024	0.024	0.048	0.072	0.096	0.120	0.144	0.168	0.192	0.240	0.360	0.480	0.600	0.720	0.840	0.960	1.080
8	1000	0.028	0.028	0.056	0.084	0.112	0.140	0.168	0.196	0.224	0.280	0.420	0.560	0.700	0.840	0.980	1.120	1.260
7	0111	0.040	0.040	0.080	0.120	0.160	0.200	0.240	0.280	0.320	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800
6	0110	0.060	0.060	0.120	0.180	0.240	0.300	0.360	0.420	0.480	0.600	0.900	1.200	1.500	1.800	2.100	2.400	2.700
5	0101	0.080	0.080	0.160	0.240	0.320	0.400	0.480	0.560	0.640	0.800	1.200	1.600	2.000	2.400	2.800	3.200	3.600
4	0100	0.100	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
3	0011	0.120	0.120	0.240	0.360	0.480	0.600	0.720	0.840	0.960	1.200	1.800	2.400	3.000	3.600	4.200	4.800	5.400
2	0010	0.140	0.140	0.280	0.420	0.560	0.700	0.840	0.980	1.120	1.400	2.100	2.800	3.500	4.200	4.900	5.600	6.300
1	0001	0.160	0.160	0.320	0.480	0.640	0.800	0.960	1.120	1.280	1.600	2.400	3.200	4.000	4.800	5.600	6.400	7.200
0	0000	0.180	0.180	0.360	0.540	0.720	0.900	1.080	1.260	1.440	1.800	2.700	3.600	4.500	5.400	6.300	7.200	8.100

Recalibrate the UTA

The switches in the UTA select many possible values for the transconductance gain. The gains are set by precision 0.1% accuracy metal film resistors. The diagram below shows the location of the gain adjustment trimmer. This trimmer can be adjusted to achieve the best possible gain on one particular switch setting. The gain at other switch settings should then fall within 0.3% of the correct value, but may not be as good as the switch position that has been trimmed.

The timmer can be adjusted as follows. Use a precision current sink as the input signal for the amplifier and an accurate digital voltmeter to read the amplifier output voltage. Set the output of the precision current sink to the desired the full scale sink current. Adjust the first stage gain trimmer to give the corresponding full scale output. For example, to calibrate for a Quantum PAR sensor, we standardize with a 16.667 microamp input current, and a 5.0 volt output voltage. The adjustment range is ± 3% of the dip switch gain value.

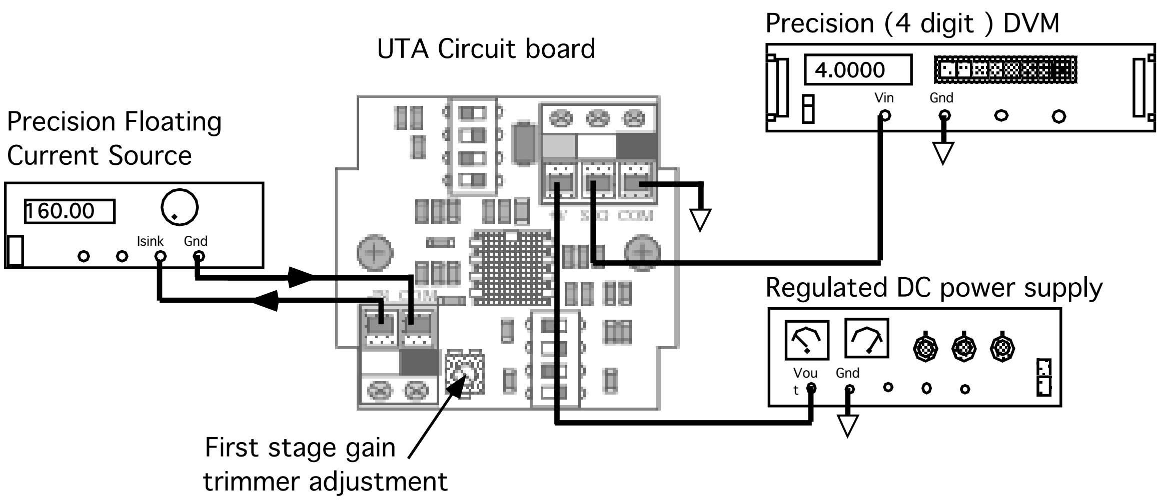

Figure 4: UTA re-calibration setup

Notes:

• Each LICOR sensor has an individual calibration tag. The standard calibration of the UTA requires that the calibration constant be entered in software. Alternatively, a UTA can be calibrated to match an individual LI-COR sensor. For example, 1000 watts/meter^2 input can give 1.00 volt output so the formula is simple (W/m^2 = volts * 1000). That UTA then has to stay with that particular LI-COR sensor. In effect the calibration is done in the hardware, rather than in the software. This simplifies the software, particularly where a low-resolution converter will be used, or where calibration constants cannot be entered in software, or where several light sensors must be interchangeable without reprogramming. The disadvantage is that if the LICOR sensor needs to be replaced or recalibrated, then its attached UTA must also be recalibrated.

For example, suppose you have a Quantum PAR sensor (LI-190), and that its calibration tag states a multiplier of -187.5 µE/m^{2}s per µA. Suppose you want to calibrate the UTA to have an output of exactly 4.0 volts when the solar input is 2000 µE/m^{2}s. Note that the sensor output when the solar radiation is 2000µE/m^{2}s will be 10.667 microamps (=2000/187.5). One way to do the calibration would be to apply a current of exactly 10.6667 microamps to the UTA input and then adjust the trimmer in the UTA to give an output of 4.0 volts. It may be more convenient to use a standard current sink, say 10 microamps, and then set the output to 3.750 volts. (=4*10/10.667). The range of the trimmer may not be sufficient to reach some settings. Please consult with EME Systems if you need special calibration for a UTA.

Alternatively, a calibrated light source such as LI-COR's 1800-02 Optical Radiation Calibrator can be used to match the sensor to the UTA. Place the sensor in the calibrator and adjust the first stage gain trimmer to match the desired voltage output. Or, you can use one recently calibrated LI-xxx as your standard for calibrating others of the same type, given a stable light source, such as stable, midday sun.

• LI-COR recommends that all LI-XXX series sensors be returned for re-calibration every two years. This will ensure proper calibration and compensate for the effects of aging and degradation on the sensor.

Troubleshooting:

1) UTA appears to be dead; the output voltage is stuck at zero or full scale regardless of light level:

Things to check:

1a) Be sure protective red plastic cap has been removed from the top of the LI-COR sensor.
1b) Check supply voltage and polarity at the red and black terminals of the UTA circuit board.
1c) Check the sensor polarity, make sure that the center conductor on the sensor wire is connected to the white terminal and the outer shield wire is connected to the black terminal on the UTA input.
1d) Check the screw terminal connections, make sure all of the wires are clamped solidly in place. The sensor wire should be clamped in the terminal, not loose underneath it. The center conductor of the sensor wire is delicate; be sure it is not broken.
1e) If you are testing the unit on a bench indoors you may have to move it very close to an artificial light source to get a response. Light levels indoors are much, much weaker than sunlight.
1f) Check that the gain selecting switches are completely pushed to one side or the other, depending on the desired gain.
1g) Has there been a lightning strike in close proximity? Although the UTA is protected against excess or reversed power supply voltages, it can not be expected to survive catastrophic extremes.
1h) Check for evidence of water entry into the cabinet. In regions of extreme humidity or precipitation it may be wise to place a dessicant, such as silica gel, inside the UTA's cabinet.

2) Amplifier seems to be responding to light, but the output seems too low or too high:

Things to check:

2a) Be sure you are using the correct multiplier in your calculations. Refer to Table 2, and the switch block positions in the box. The version of the UTA number should be printed on the top label or on the calibration label. Be sure the UTA version matches with the version of the instruction manual.
2b) Place sensor in full unobstructed sunlight, you should see a significant increase in output voltage. Indoor lighting is much, much weaker than full sunlight. The standard amplification factors are designed to accommodate full tropical sunlight conditions. If you will be using your sensor in generally low-light conditions, say indoors, in the arctic, under a plant canopy, or in deep water (LI-192 or LI-193), you may wish to select a higher output voltage setting to bring the signal into the dynamic range of your data logger. Please consult the LI-COR literature and references, or contact EME Systems for assistance.
2c) The power supply must be at least 2 volts greater than the desired full scale output voltage (except the UTA/HOBO version, which operates rail to rail).

3) The amplifier output is unstable and readings fluctuate too much under constant lighting conditions:

Things to check:

3a) Check all of the connections to the screw terminals. Make sure all connections are tight and secure.
3b) Check for an AC component in the power supply voltage. The power supply should be filtered direct current and should stay at least 2 volts above the full scale output voltage.
3c) Is the sensor close to a strong electromagnetic field, such as a halide lamp or a refrigerator motor or other AC power equipment? If so, try to reroute the sensor cable, or run the sensor cable inside a grounded metal conduit. Avoid running the sensor cable in the same conduit as AC power lines.
3d) Occasionally, oscillations can arise due to reactive loading on the signal cable. Placing a 0.1µF capacitor between the signal terminal and the common terminal at your data logger input will usually suppress the oscillation.

UTA, Polycarbonate Enclosure, Physical Dimensions:

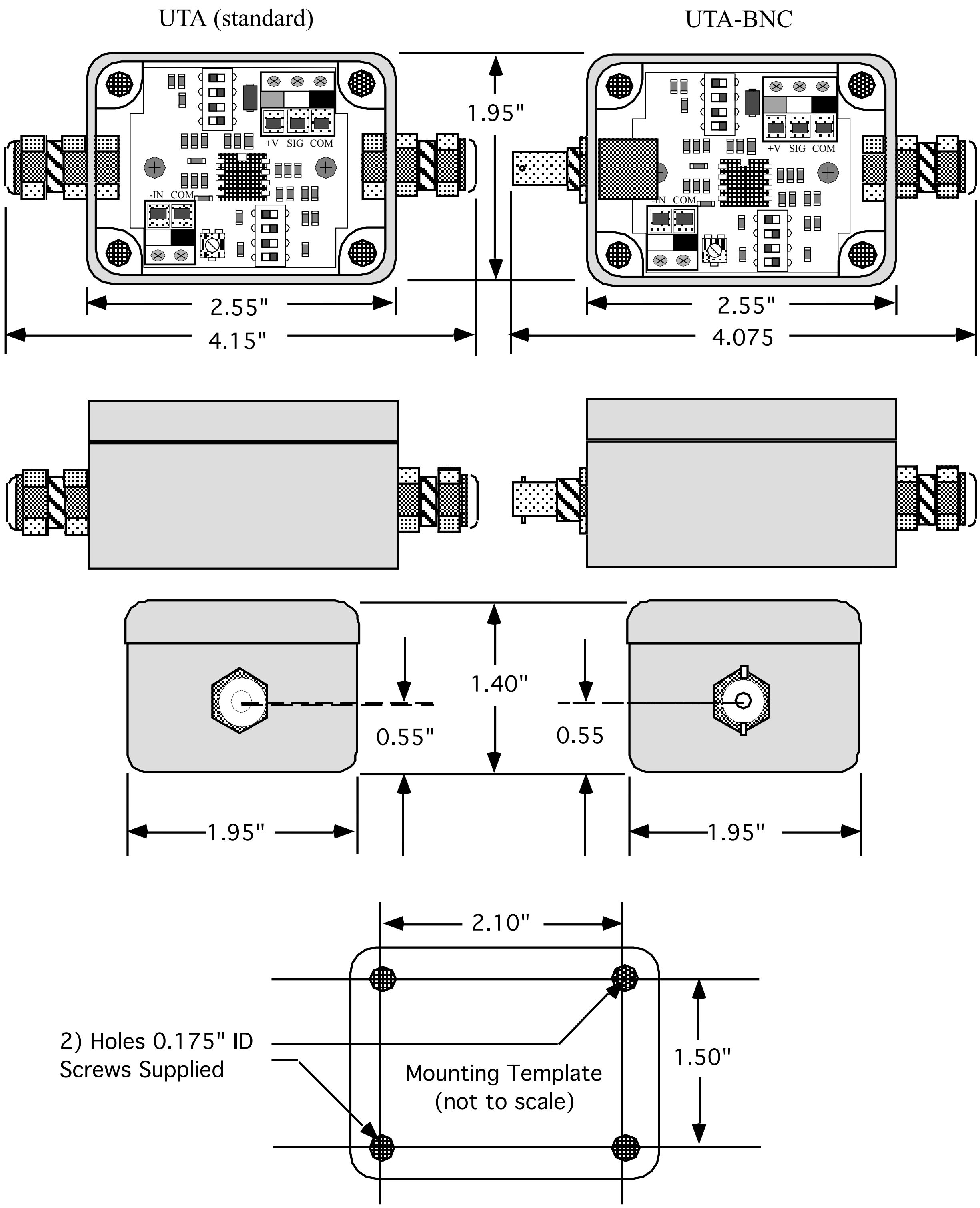

Figure 5: UTA enclosure, physical dimensions

UTA Schematic:

The information contained herein is provided as an aid to resolving questions about the amplifier and its application. It is not meant for general distribution and remains the exclusive property of EME Systems.

UTA — Universal Transconductance Amplifier - Version 2

Version 2, Rev. A UTA June 2006 (UTA06g)
EME Systems, 2229 Fifth St., Berkeley CA 94710
tel: (510) 848-572, fax: (510) 848-5748
www.emesystems.com, info@emesystems.com

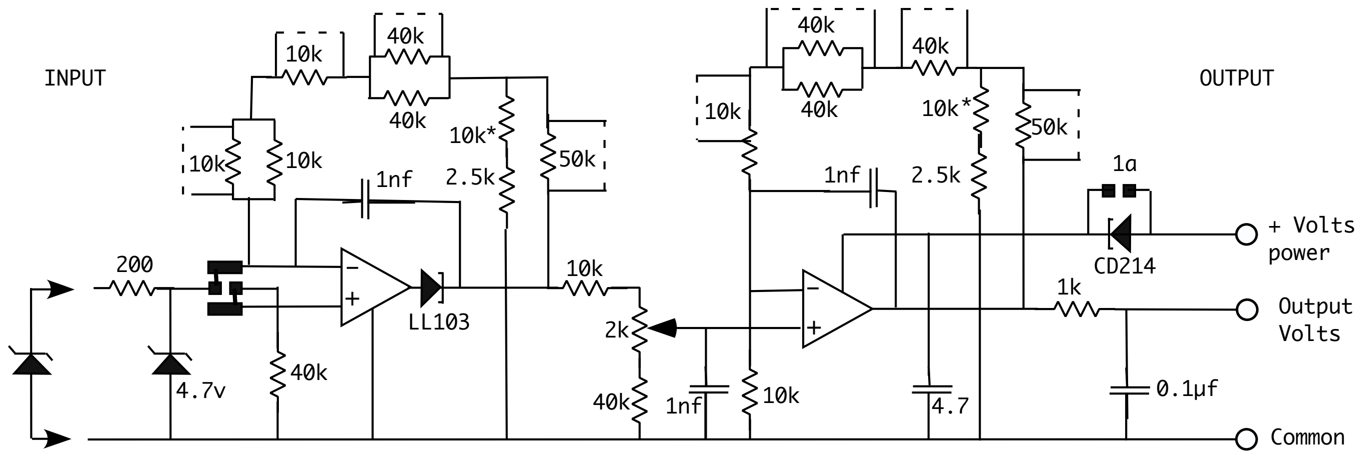

Figure 6: UTA schematic diagram

Switches are represented as dashed lines, and are either open or closed to allow or short the parllel resistor(s).
Switches on input stage select transconductance gains from 0.004 to 0.18 volts per microamp.
Switches on output stage select voltage gains from x1 to x45.
Composite gains from 0.004 to 8.1 volts per microamp.
High gain settings use split T feedback.
Provision is made for a solder jumper on the bottom of the circuit board to boost the first or second stage gain by shorting the 10kΩ resistors marked with * in the split T networks. Gains of 28 volts per microamp are possible for low light levels.
There is also provision on the circuit board for a voltage regulator for the power supply, which would replace diode CD214.
Special for Onset HOBO®, jumper 1a shorts diode.

Op amps for this circuit are socketed to allow field replacement and also to allow substitution of alternative op amps for special purposes: low light levels, special supply voltages or micro-power, high speed operation, dual output. Some special options my also entail changes to gain or compensation components.
Standard gain op amp:
LT1490I: 220µVos, 4naIb, 200khz GBP, r-r i/o, 2V–44V, 100µa power, PSRR=98db
LT1078I: 70µVos, 6na Ib, 200khz GBP, output to Vd-0.8V, 5V–44V 100µa power, PSRR=114db
Low offset high gain highest accuracy CAZ op amp:
LTC1051: 1µVos, 15pa Ib, 2.5mhz GBP, output to Vd-1.5V, 5V–16V 2ma power, PSRR=140db
LTC2055HV: Similar to the LTC1051, but operates on lower power supply voltage and current.
Higher speed:
TLV2462: 500µVos, 1na Ib, 6.4mhz GBP, r-r i/o, 2.7V–5.5V, 1ma power, PSRR=95db.
LTC6241: 125µVos, 1pA Ib, 18mhz GBP, r-ro, 2.8V-11V, 3ma power, PSRR=104dB, low noise CMOS.

Appendix: UTA–HOBO

The UTA–HOBO is designed as a precision interface between LI-COR light sensors (Quantum PAR, Pyranometer or Photometer) and the Onset HOBO data logger. LICOR sensors provide a small signal in the range of microamps, whereas the HOBO inputs require a signal in the range of 0–2.5 volts. The UTA–HOBO provides this amplification, and it also has features that allow it to operate directly from the HOBO power supply.

The UTA–HOBO is manufactured in two models. The base model ("UTA–HOBO") is for use with a SZ model LI-COR sensor, while the "UTA–HOBO/BNC" is for use with the SA model LI-COR sensors which have BNC connectors. It should be noted that BNC connectors are not waterproof, and should be used only in areas that are sheltered from water exposure. For best water resistance, use the SZ model LI-COR sensors Additionally, both the UTA–HOBO and UTA–HOBO/BNC are available with a high-precision, high-gain setting for use in low light level conditions (e.g. indoor lighting studies, or deep water studies using the LI-192 or LI-193). Please specify either UTA–HOBO/HG or UTA–HOBO/BNC/HG for the high gain option.

The HOBO power supply is a small 3V lithium battery, but despite its small size, it is capable of operation for long periods of time between battery changes. Most of the time, the HOBO is in a sleep mode wherein it requires little power. At a specific time interval (which you determine when you launch the HOBO), the data logger wakes up, turns on the external power supply (red wire on the HOBO-volt cable), and records the data coming in from the sensors. The UTA is powered from the 2.5 volts provided by the HOBO during the measurement interval. The UTA draws about the same current (125 µamps) as the Onset thermistor temperature probe, so the UTA–HOBO does not compromise the HOBO battery life. In the UTA–HOBO, some components of the base model UTA have been replaced in order to meet the special low voltage, low current, and high speed, requirements of the HOBO data loggers.

Figure 7: UTA to HOBO connection - A UTA serves as a link between a LI-COR sensor and the Onset HOBO data logger. The UTA amplifies the tiny current signal from the LI-COR sensor and outputs a voltage compatible with the HOBO.

1) 12-bit DC voltage input adapter (Onset Part# S-VIA-CM14) required for UTA connection to HOBO weather station (H21-001) and HOBO micro-station (H21-002) dataloggers.
2) Cable-2.5-Stereo (Onset Part #HOBO-VOLT) required for UTA connection to H8 and U12 series HOBO dataloggers

Connect the UTA–HOBO input and output:

Figures 8 and 9, the UTA–HOBO Connections Diagrams, on the following page, lay out connections between the UTA, the LI-COR sensor, and the Onset® HOBO data logger. The connection between the UTA and the HOBO depends on the type of HOBO data logger you are using:

- **HOBO H8/U12 series:**
  Use the HOBO-Voltage cable from EME Systems or the "cable-2.5-volt" from Onset (Onset Part #HOBO-VOLT). to connect he UTA–HOBO to the HOBO . The mini stereo plug connects to one of the input ports on the side of the HOBO data logger. The other end of the cable end has three bare wires and goes through the gland nut on the side of the UTA nearest the three-position terminal on the UTA circuit board. The wires are screwed down under the terminals according to color code: Red to Red, White to Green, Black to Black.

- **HOBO weather station (Onset Part #H21-001) and HOBO micro-station (Onset Part #H21-002):**
  Use the 12-bit DC voltage input adapter (Onset part #S-VIA-CM14) to connect with the UTA–HOBO. You will need a 3-conductor cable to connect between the UTA–HOBO and the voltage input adapter. Make the following connections between the 3-terminal block on the UTA–HOBO and the voltage input adapter: terminal-block red connects to "TRIG. SOURCE"; terminal-block green connects to "VOLTAGE INPUT", and terminal-block black connects to "GROUND". Once these connections have been made, plug the voltage input adapter into the HOBO datalogger via the RJ11 (telephone-type) connection.

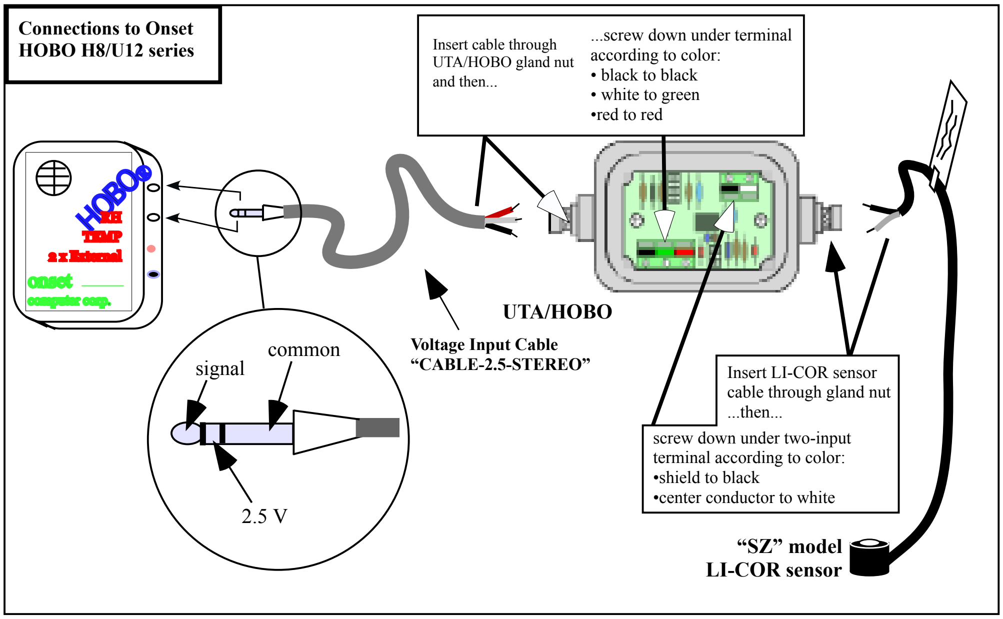

Figure 8: UTA to HOBO H8/U12 series

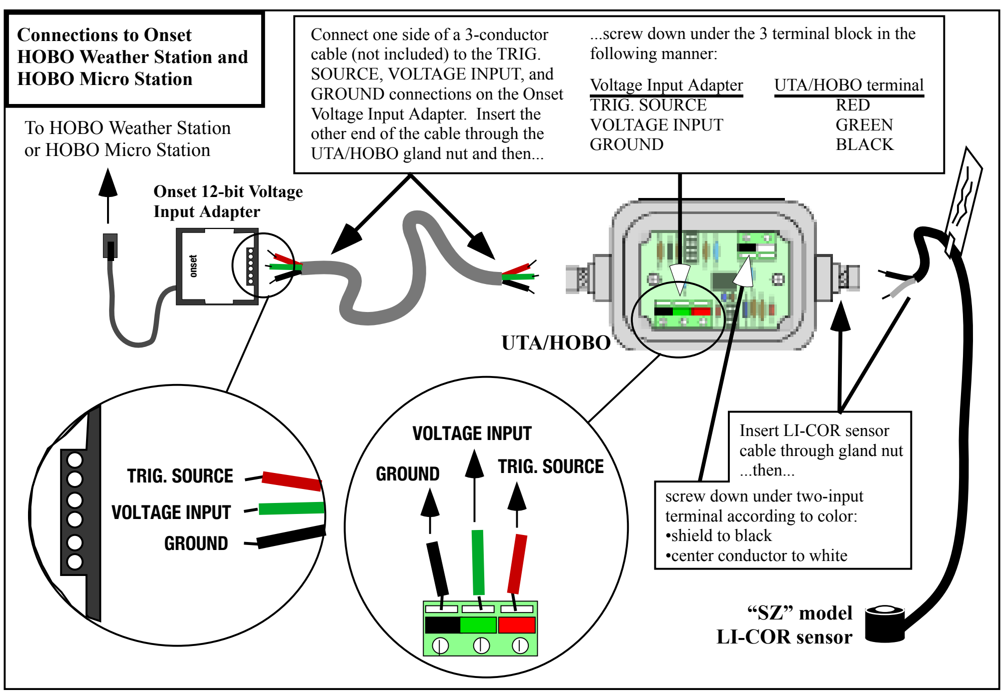

Figure 9: UTA to Micro Station and Weather Station

Calculate the light level:

The external channels on the Onset HOBO data loggers record voltage. When you acquire readings from the logger, using the ONSET® Boxcar software, those readings will be in volts. You will want to convert Volts to units of light measurement. Drop the negative sign from the LI-COR sensor multiplier when making this conversion.

$$\textbf{Light Level} = \frac{\textbf{(UTA–HOBO volt output)*(sensor gain)}}{\textbf{(UTA–HOBO transconductance gain)}} \qquad \textit{(equation 3)}$$

Table 4: Gain Settings for UTA/HOBO

	UTA–HOBO/190*	UTA–HOBO/200	UTA–HOBO/210
UTA Transconductance Gain (V/µA)	0.16	0.02	0.056
Switch Settings (S1,S2)	S1=5, S2=14	S1=14, S2=11	S1=8, S2=14

*Note that LI-190, LI-191, LI-192, and LI-193 Quantum PAR sensors all use the same transconductance gain.

Examples of light level calculations for UTA–HOBO:

Below are examples that show the conversion from Volts to light level for different types of LI-COR light sensors.

LI190 Quantum PAR sensor example:

- **Switch settings S1=5, S2=14, gain = 0.16 volts per microamp**
- UTA–HOBO gain = 0.16 volts per microamp (2.5 Volts full scale output at 15.625 µamps input)
- multiplier, from LI190 calibration tag or certificate = 145.00 µmoles/m^{2}s per µamp (hypothetical)
- Volts reading from HOBO = 1.25 V (hypothetical)

=> light level = HOBO Volts * [145.00 / 0.16] = (1.25 volts) * (906.25 µmol/m^{2}s per volt) = **1132.8 µmoles/m^{2}s**

LI200 Pyranometer sensor example:

- **Switch settings S1=14. S2=11, gain = 0.02 volts per microamp**
- UTA–HOBO gain = 0.02 volts per microamp (2.5 volts full scale output at 125 µamps input)
- multiplier, from LI200 calibration tag or certificate = 11.50 watts/m^2 per µamp (hypothetical)
- volts reading from HOBO = 1.25 V (hypothetical)

=> light level = HOBO volts * [11.50 / 0.02] = (1.25 volts) * (575.0 watts/m^2 per volt) = **718.8 watts/m^2**

LI210 Photometer sensor example:

- **Switch settings S1=8, S2=14, gain=0.056 volts per microamp**
- UTA–HOBO gain = 0.056 volts per microamp (2.5 volts full scale output at 41.667 µamps input)
- multiplier, from LI210 calibration tag or certificate = 2.88 klux per µamp (hypothetical)
- volts reading from HOBO=1.25 V (hypothetical)

=> light level = HOBO volts * [2.88 / 0.056] = (1.25 volts) * (51.42 klux per volt) = **64.3 klux**

Values in the box above are typical for full sun readings. Those will be fine for many purposes. But for low light conditions or for use with other sensors, you may wish to set a different gain. The switch settings inside the UTA can be manipulated with reference to the chart on page 6. There are a couple of guidelines for choosing the gain of stage 1 and stage 2. For the HOBO, the gain of stage 2 should be x2 or greater. (S2 setting 14 or less, not 15). Within that constraint, it is best to use the highest gain possible on stage 1, switch S1.

Note: There is a 4.5 millisecond pause between the wake up and the first measurement. Subsequently, it takes up to four measurements spaced 14.5 millisecond apart, then the power supply turns off and the HOBO goes back to sleep. It may be best to connect the UTA-HOBO to one of the later HOBO channels to allow more time for warm-up.