Irradiance Measurement

The efficiency of a solar panel, η_{panel}, can be defined as the ratio of the electrical power out of the panel, P_{out}, to the optical power into the panel, P_{in}. The output power is simply the product of the output current, I_{out}, and the output voltage, V_{out}. The incident optical power is the product of the incident irradiance, E_o, and the panel area, A_{panel}. Thus,

$$\eta_{panel} = \frac{I_{out} V_{out}}{E_o A_{panel}} \tag{1}$$

In the present experiment, E_o, I_{out}, and V_{out} are measured and used directly to determine the panel efficiency.

The irradiance (in μW/cm^2) is measured in terms of a voltage using a light-to-frequency converter (TAOS TSL230R-LF) in conjunction with a frequency-to-voltage converter (Analog Devices AD650). For this system, several conversions are needed to determine the irradiance from the measured voltage. This is shown in Figure 1.

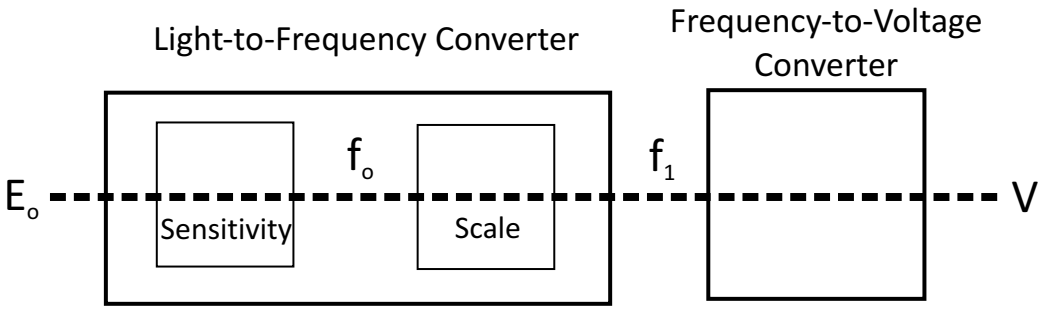

Figure 1: Schematic of irradiance-to-voltage measurement system.

In order to determine the irradiance from the measured voltage, each conversion must be specified, working backwards from the output voltage to the input irradiance.

The input frequency, f_1, to the AD650 is determined from the AD650's voltage output, V, by

$$f_1 = 2.2V - 0.035, \tag{2}$$

where V is in volts and f_1 is in kHz.

The input/output relation for the TSL230R-LF to determine the irradiance, E_o, from f_1 depends upon the switch setting of the light sensor box. There are 12 switch settings, each corresponding to specific sensitivity and scale values. The sensitivity setting corresponds to a gain of 1, 10, or 100 that occurs between E_o and f_o. The scale setting signifies a reduction of 1, 2, 10, or 100 in going from f_o to f_1. The settings are given in Table 1.

Switch	**Sensitivity**	**Scale,** S	B
0	100	100	0.114
1	100	10	0.114
2	100	2	0.114
3	100	1	0.114
4	10	100	1.114
5	10	10	1.114
6	10	2	1.114
7	10	1	1.114
8	1	100	2.114
9	1	10	2.114
A	1	2	2.114
B	1	1	2.114

Table 1: Irradiance detector switch settings.

The relationship between f_1 and f_o is

$$f_o = S f_1, \tag{3}$$

where S is the scale given in Table 1.

The frequency f_o is related to E_o as shown in Figure 2. In this figure, there are three solid lines, each corresponding to a specific sensitivity setting. The top line has a sensitivity of 100, the middle line a sensitivity of 10, and the bottom line a sensitivity of 1.

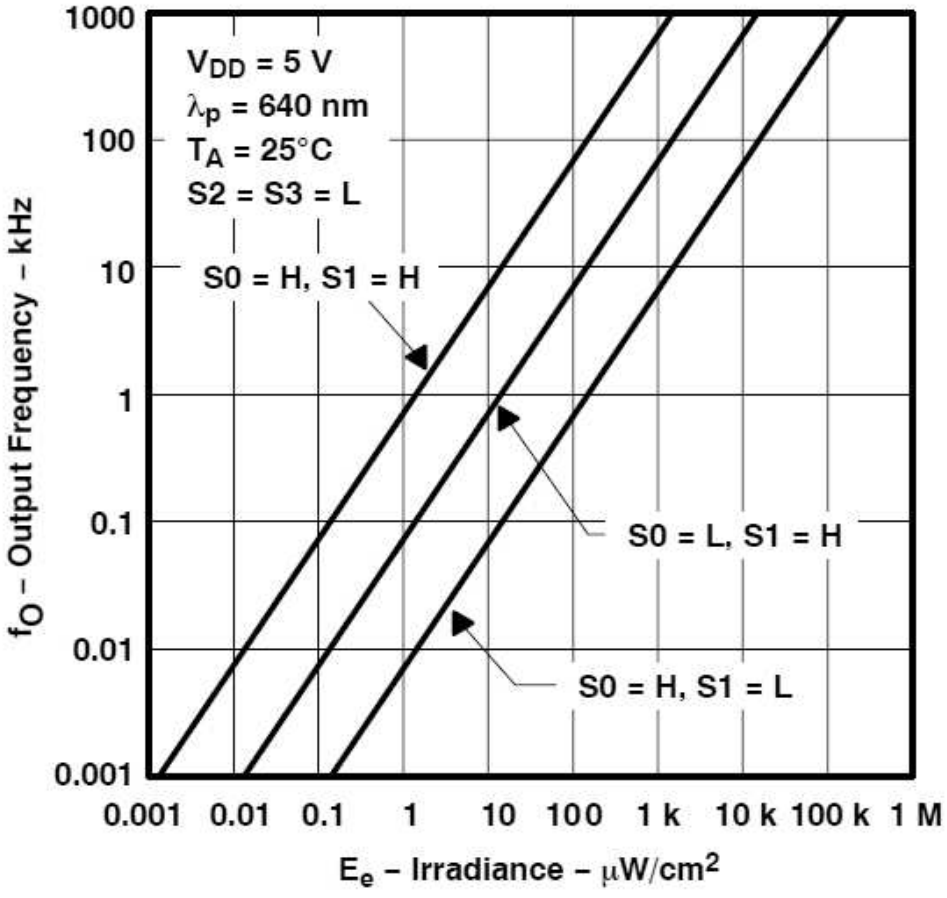

Figure 2: Output frequency versus irradiance (Source: TAOS079A-October 2006 Data Sheet).

For the three sensitivity settings, E_o is related to f_o as

$$\log f_o = \log E_o - B, \tag{4}$$

where B is a constant. This equation can be rearranged to give

$$E_o = 10^B f_o. \tag{5}$$

The values of B for each of the three sensitivities are given in Table 1. Finally, equations 2, 3, and 5 can be combined to yield the desired relationship between E_o and V,

$$E_o = 10^B S(2.2V - 0.035). \tag{6}$$