Basic Stamp Experiments Using the TSL230

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This application note is intended for the novice experimenter. For more accurate and technical information, please refer to TSL230.pdf available from http://www.taosinc.com

The TSL230 is a device that generates a frequency that changes in direct proportion to the amount of light incident on it. The shortest description of its use is this: Light comes into the chip and strikes a scalable photo-array, and that array produces a voltage that drives a voltage-controlled oscillator. The result is an eight-pin chip, smaller than a dime, which can give us a clock pulse with a frequency that represents a specific intensity.

Photocells and photo-resistors do a similar task. Light incident on those devices is converted to quantities we can readily measure on digital multi-meters: voltage and resistance. And we might be able to get away with measuring resistance on the Stamp with the command RCTIME, but the result would be an ever varying time base, subject to moisture, lead length, temperature, and a myriad of other factors. And without external circuitry such as a voltage-controlled oscillator, or an analog to digital converter, we'd have quite a time acquiring accurate data with the Stamp. The TSL230 takes care of everything for you, and can do so in only one stamp I/O line. (We use more for the initial setup, but the four extra wires could easily be hardwired to logic levels high or low)

This chip might be used as part of an extremely accurate photogate or to measure the loss in a length of fiber optic cable. Also it might be used to measure a patient's blood pressure by sensing the variations in transmittance through a finger, or even detecting the fluctuations in light intensity that are inherent to our AC lines. The introductory experiments presented here will take us into the realms of screen flicker, and the "flicker" of many light sources. But if you're feeling slightly more ambitious, see the last page for more project ideas.

The Stamp has a command called **COUNT** that can count the number of clock cycles over a set period of time. This is useful for us because the output of the TSL230 is a clock source. All we have to do is to supply power to the chip, connect a few jumper settings, and we can start taking data immediately. Plug a TSL230 into the prototyping area, supply power to it via the onboard regulated supply, and connect the remaining pins to suitable Stamp I/O pins.

TSL230 abridged data sheet

Pin	Function	I/0	Connect to:	Pin	Function	I/O	Connect to:
1	S0, Sensitivity Select	I	Stamp I/O pin 0	5	Supply Voltage		Vdd
2	S1, Sensitivity Select	I	Stamp I/O pin 1	6	Out	O	Stamp I/O pin 5
3	Output Enable (OE')	I	Stamp I/O pin 4	7	S2, Fo scaling-select input 1	I	Stamp I/O pin 2
4	Ground		Vss	8	S3, Fo scaling-select input 2	I	Stamp I/O pin 3

S1	S0	Sensitivity	S3	S2	Fo scaling (divide by)
L	L	Power Down	L	L	1
L	H	1 x	L	H	2
H	L	10 x	H	L	10
H	H	100 x	H	H	100

The Basic Stamp II can only count to 65,535 (word). Your choices for the settings on the TSL230 should come as close to using the full scale as possible without exceeding it. Now lets write a short program that can utilize the TSL230. To start, use Sensitivity = 10 x, and Fo scaling = / 2. To make a pin low or high, simply type **LOW *pin*** or **HIGH *pin***. Each pin must be set to either logic level LOW (0_Volts) or HIGH (5_Volts). Try taking measurements every 1_ms for two seconds (utilize FOR…NEXT loop to accomplish this) and see if this is too high or too low to view the 60_Hz frequency of alternating current. A sample of the program you might use is provided.

```
'-----Define variables, set status of pins-----
x      VAR   WORD
cnt    VAR   WORD
S0     CON   0
S1     CON   1
S2     CON   2
S3     CON   3

LOW   S0                       'Sets status of TSL230 pins
HIGH  S1
HIGH  S2
LOW   S3
HIGH  4                        'Toggle state to enable/disable chip

'-----Main program loop-----'
FOR x = 1 TO 2000
COUNT 5, 1, cnt                'Count on pin 5 for 1 ms, store value in cnt
DEBUG DEC cnt, CR              'Send value of cnt, as a decimal to the computer
NEXT                           'Do it all over again, 2000 times
END
```

***Note: The first time I did this, I expected to see a nice clean sine wave appear on the screen. This is not the case. Hopefully though, you will see that incandescent light is far from a consistent, steady light source.

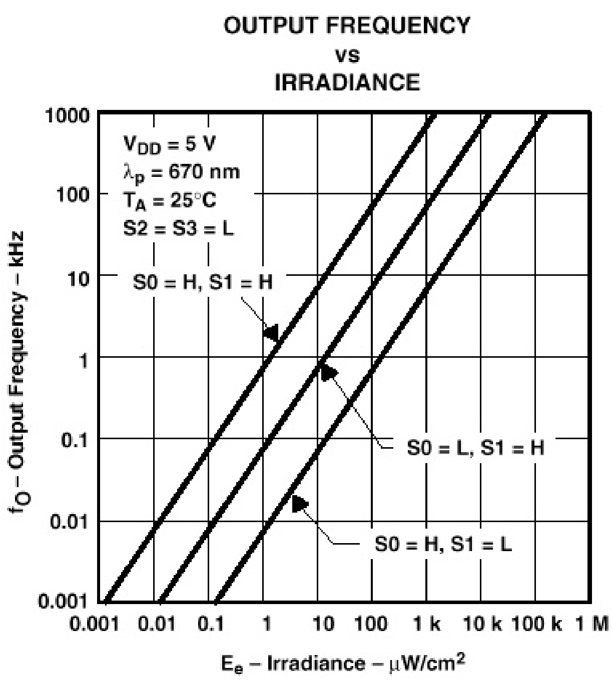
Computer monitors refresh the screen at set rates (say, 60_Hz, 1/60=0.016, so at the maximum resolution of the stamp, 0.001 sec, we'd expect to see a period of 16 samples. Turns out we don't. This is caused by the delay in transmitting the data using **DEBUG**. The stamp cannot count while it is transmitting, so time it lost. Also, time is lost to reading and writing to the Ram, although this is quite minimal. Wire the chip and the stamp, and set the detector in front of the computer screen. Manipulate the settings until your data starts to present marked fluctuations in data. If you are unable to view some screen flicker, turn the monitor off, and let the sensor record the fluctuations in intensity of ambient light. Data is best interpreted here by http://www.selmaware.com Stamp Plot Lite or Stamp Plot Pro. You will not likely be able to calculate the refresh rate directly from the plot. But if you'd like to see a better shot of the data, copy it to Mathematica or Excel and perform a Fourier Transform (FFT).

Calibration:

Finding a common household object that can offer a uniform calibration benchmark turns out to be a formidable task. Without one though, we can provide only qualitative measurements. For many uses such as absorption spectroscopy, this is good enough -- Often we only care about relative levels of light. But some uses, such as building a light meter for photographic purposes, require a somewhat more delicate measurement.

The first thing to remember is that the TSL230 provides scalable output. By accidentally programming pin S1 to logic level high, instead of low, you might see output that is 100x larger than expected. And by sampling for 10000 milliseconds rather than 1000, you would further increase the counts collected over time. I haven't been in a situation yet that too few counts are a problem. One thing to note is that the output frequency varies with supply voltage, so see to it that the voltage supply doesn't vary. Also, put a .1 μF capacitor between the supply voltage and ground. This helps to decouple the supply lines – is averages any small fluctuations in voltage over time.

The photodiode area averages 1.36_mm^2 (.0136_cm^2) as printed in the TSL230 data sheet. The graph below, also from the data sheet, shows that the frequency measured in kilohertz varies directly with the Irradiance as measured in microWatts per square centimeter. And this is only for 670nm. There is variation with the frequency of light as well.



All of this information is a little scary, but it will make more sense with a few calculations. Let's pretend we're playing with the sun, and we'll make this a big stretch and say that the sun only radiates 670_nm light. (This way, we can use the graph to the left without making any adjustments). And we'll pretend that we're counting for a full second, so our frequency is in Hertz.

S0=L, S1=H; F0=10,000 counts/second=10 kHz. How many Watts of power are hitting the photo-detector array of the TSL230?

The thick middle line is the one to use here. And that line tells us that 10 kHz on the graph corresponds to around 100 μW/ cm^2. So the power incident on the array is (100 μW/ cm^2)*(.0136_cm^2)=1.36 μW of power.

Now we have a way of measuring the power hitting the photo-array of the TSL230. Happy Experimenting. For further experiment ideas, look below.

Further Information and Suggested Readings:

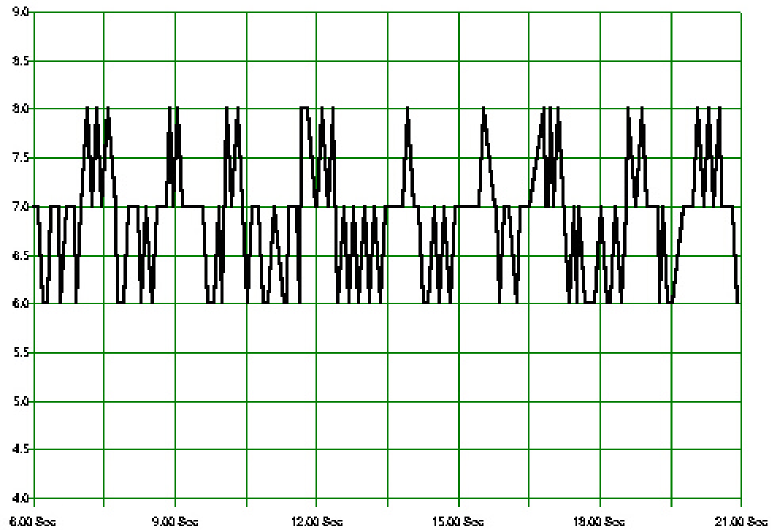
The Photoelectric Effect, The Energy of Light, and the DeBroglie Wavelength:

When photons strike an atom, they can bump electrons to higher energy levels. If they fall back down, they emit radiation, sometime visible light. If the electrons leave the atom, they begin to flow, and generate a current. Photovoltaic cells work this way. I hate to say it, but the Chemistry books usually offer a better explanation of what's going on than Physics books. Try Fundamentals of Physics, 5^{th} Edition – Halliday, Resnick, and Walker. Or Chemistry, 2^{nd} edition, Olmestead and Williams

I allowed myself a certain amount of license above when dealing with energy and power in the writing of this. The energy of light is dependent on its frequency, not its intensity. Remember seeing darkrooms in movies illuminated by red light? Red light just doesn't have the energy of Blue or Violet light. I could have all of the red light I wanted shining in that room without destroying the film, but even a small amount of violet light might destroy it. I'm not going to trouble you with the details, well yes I am. The frequency of light is related to the wavelength by $c=\lambda f$, where c is the speed of light, λ is the wavelength, and f is the frequency. The energy is related by the equation $E=hf$, where E is the energy, h is Plank's constant (6.626*10^-34 J*s), and f is the frequency. That same 670_nm light from above has a frequency of 4.48*10^14_1/s. Plugging that in, we get an energy of around 3*10-19 Joules, or 1.85 eV.

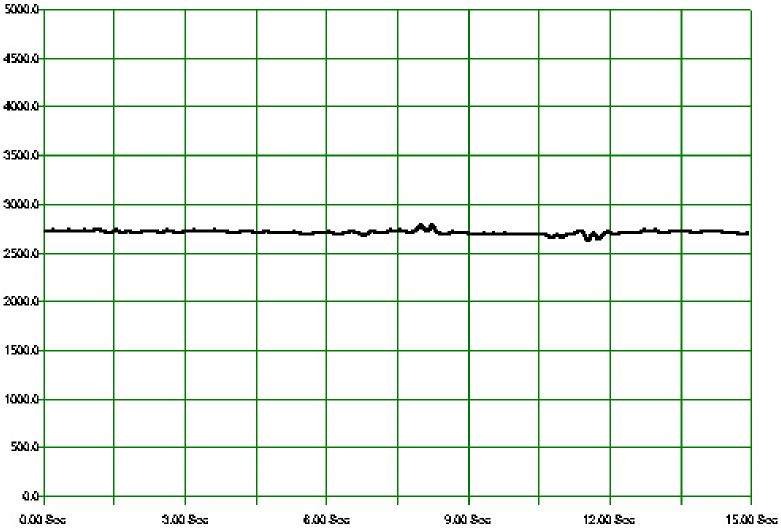
This is all awful confusing the first dozen or so times around, so hit the library. Any physics book or chemistry book should help you. I suggest trying quite a few, until you find an author that suits you. Feynman's Lectures on Physics is always a popular choice. But once you understand the process, and understand it well, you'll be able to explain away the mysteries of Chlorophyll and photosynthesis without using buzzwords like "light and dark reactions" or "ATP". I still often wonder if any introductory biology student really knows how photosynthesis works, or if they've just memorized all of the polysyllabic words in the book.

If you're feeling lucky, see if you might not be able to devise an experiment that allows you to calculate Plank's constant using an LED and the TSL230. There would be a lot of work here, but I see it as a doable activity. Might make a nice science project.

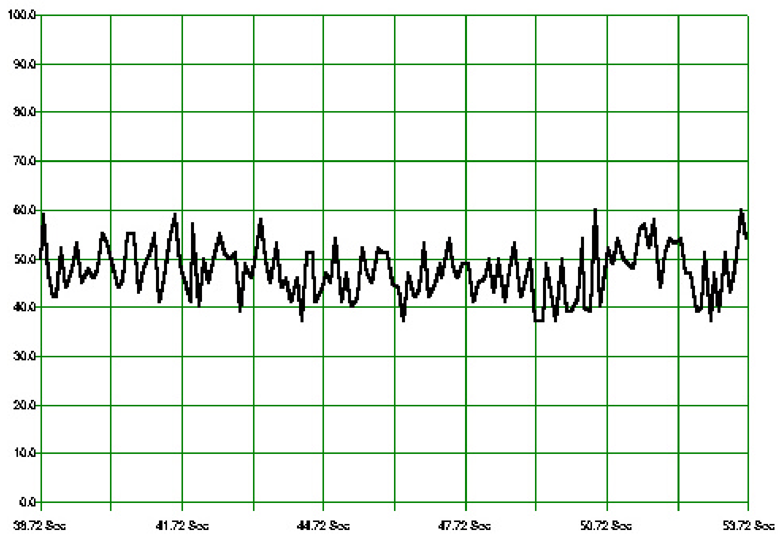


Computer Monitor (Point blank range, .01s intervals)

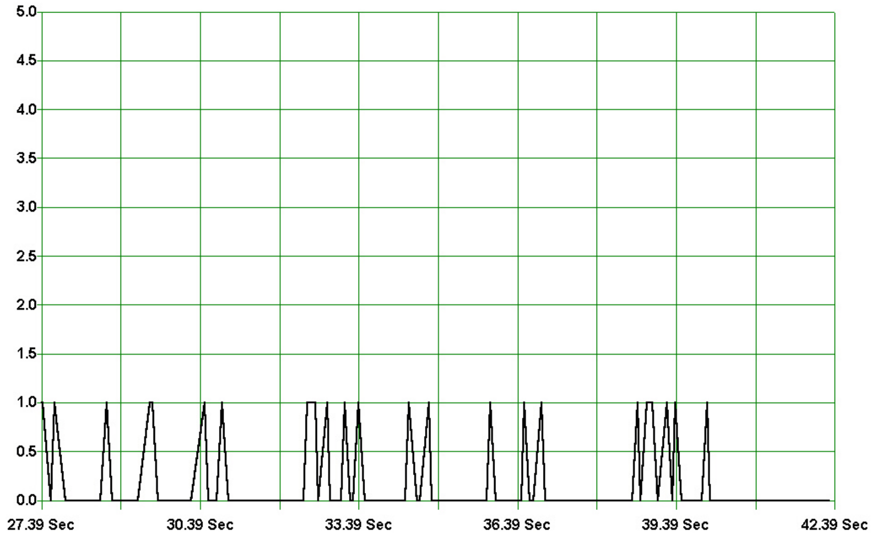
Laser Pointer (Point blank range, .01s intervals)



Flashlight
(Point blank range, .01s intervals)



Beautiful Summer Day through a window. (Again, taken at .01s interval.)



LED in a dark box. (5cm distance, 1ms intervals)

Some other things to consider trying:

1. For a finger-cuff type blood absorbency monitor, find a light source that offers very little fluctuation (no more than 2 parts per period). Such as a battery driven LED, or who knows, maybe you'll get lucky with a low voltage light bulb. You'll need a way to secure the TSL against the finger and the light source against the opposite side (so a source that doesn't get too warm). Even the slightest fluctuations in movement might register as false measurements. Try your index, thumb, pinky, maybe even the earlobe or other parts of the body. As your heart pumps blood through your body, the pressure and amount of blood in your veins changes. This pressure change should change the amount of light absorbed by the body, and the amount passed to the TSL. See what happens with different color LEDS, or even white light.
2. For an accelerometer: Secure a short piece of fiber optic cable to an LED or a laser diode. Put it in a dark box and secure the TSL230 opposite it. Any acceleration (in two dimensions only) will deflect the cable as a beam under uniform load. The deflected beam will allow a different amount of light to hit the TSL230 photo-array. You can calibrate it on a turntable and maybe use it to find the acceleration in elevators or on roller coasters.
3. For a photospectrometer: Mount the TSL230 on an extension arm, and mount the arm to a servo. Directly above the servo, secure a diffraction grating. You can then point the contraption at a uniform gas source and perform some Saturated Absorption Spectroscopy experiments. If you need help with how to get going on this one, just give a holler. It turned out to be a more daunting task than I first anticipated.
4. Use the photospectrometer to do some experiments with Saturated Absorption Spectroscopy. Pure white light is passed through a substance and the atoms and molecules in there absorb certain frequencies of light. The result is a spectrum with certain lines missing. Those lines are distinct for different substances and can be used to determine what substances are in an unknown sample. Ever wonder how they know the sun is made of Hydrogen and Helium, and what all else? You guessed, spectroscopy.