

INTELLIGENT OPTO SENSOR DESIGNER'S NOTEBOOK

Number 5



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 digital clock source 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 detector array, and that array produces a current that drives a current-to-frequency converter. The more light that hits it, the higher the current, and the higher the output frequency. The result is an eight-pin chip, smaller than a dime, which can give us a clock source whose frequency represents a specific intensity of light.

Photocells and photo-resistors do a similar task. Light incident on those devices affects the voltage and resistance across their leads. 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 I/O line of the Basic Stamp from Parallax, Inc. (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. Or it might be used to measure a patient's blood pressure by sensing the variations in transmittance through a finger, or detecting the fluctuations in incandescent 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 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 on-board regulated power supply, and connect the remaining pins to suitable Stamp I/O pins.

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HIGH S1
HIGH S2
LOW S3
LOW 4

‘Toggle state to enable/disable chip – change this if there is no
‘output from the TSL230

‘-----Main program loop-----‘

FOR x = 1 TO 2000

COUNT 5, 1, cnt

DEBUG DEC cnt, CR

NEXT

END

‘Count on pin 5 for 1 ms, store value in cnt

‘Send value of cnt, as a decimal to the computer

‘Do it all over again, 2000 times

***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 is 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).

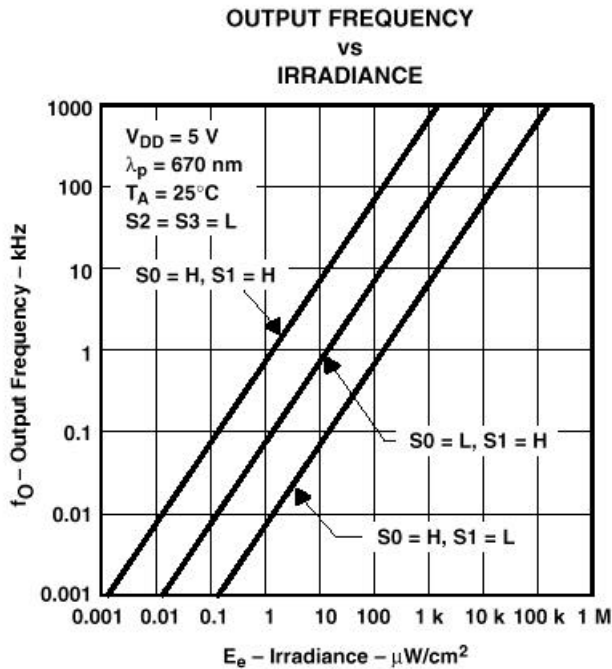
Calibration:

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 bgic 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 (*The power supply voltage sensitivity of the TSL230 output frequency is typically 0.5% per volt. – Ed.*). Also, put a 0.1 μ F capacitor between the supply voltage and ground. This helps to decouple the supply.

The photodiode area averages 1.36_mm² (.0136_cm²) 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 some variation with the wavelength 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. $S_0=L, S_1=H$; $F_0=10,000$ counts/second=10 kHz. How many μ 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 $100\ \mu\text{W}/\text{cm}^2$. So the power incident on the array is $(100\ \mu\text{W}/\text{cm}^2) * (.0136\ \text{cm}^2) = 1.36\ \mu\text{W}$ of power.

Now we have a way of quantitatively measuring the power hitting the photo-array of the TSL230 (As mentioned above, the TSL230 responds differently to different wavelengths. Therefore output frequency depends both on radiant power and wavelength. Power readings derived from the above curve only apply for a fairly narrow-band source, such as an LED, with a principal wavelength of 670nm. – Ed.) Happy Experimenting.

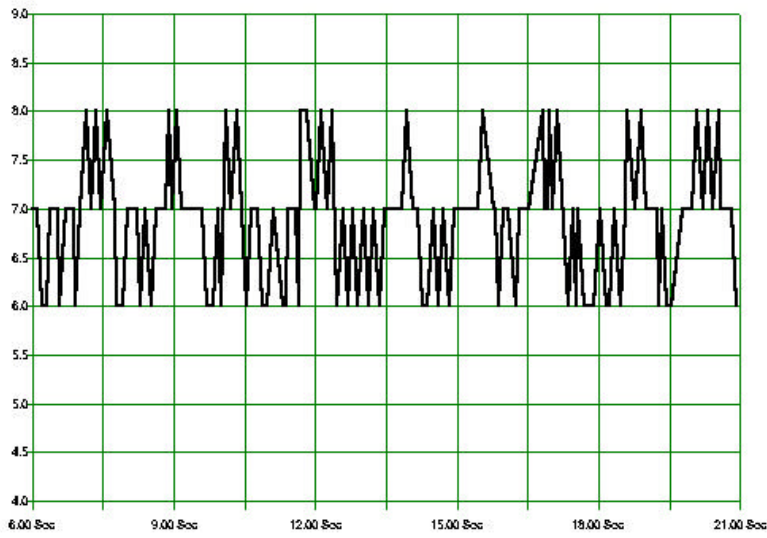
Further Information and Suggested Readings:

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

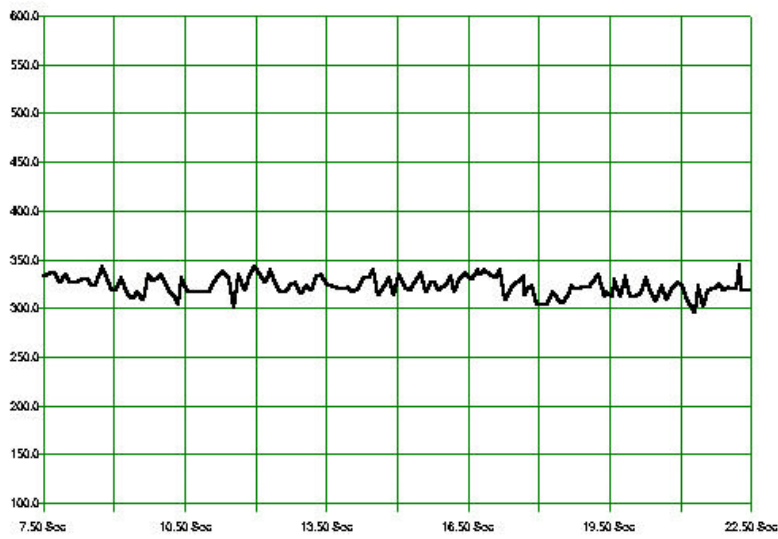
When photons strike an atom, they can bump electrons to higher energy levels. If they fall back down, they emit radiation, sometimes visible to us as light. If the electrons instead leave the atom, others fall in to take their place, they seem to begin to “flow”, and generate a current. Photovoltaic cells work this way. Photons strike atoms, electrons leave, and other electrons fall into the holes created by the fleeing electron. 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, 5th Edition – Halliday, Resnick, and Walker. Or Chemistry, 2nd edition, Olmstead and Williams

I allowed myself a certain amount of license above when dealing with energy, power, irradiance, and illumination in the writing of this – operationally defining these terms for the user was not my goal in writing this paper. The energy of light is dependent on its frequency, not its intensity. Remember seeing darkrooms in movies illuminated by red light? Red light has less energy than Blue or Violet light. You can have all of the red light that you want shining in a darkroom without destroying the film, but even a small amount of violet light can damage it. The frequency of light is inversely proportional to the wavelength [$f=c/\lambda$], where c is the speed of light, λ is the wavelength, and f is the frequency. The energy of the photon is related to the frequency by the equation [$E=hf$], where E is the energy, h is Planck’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, you get energy of around 3×10^{-19} Joules, or 1.85 eV.

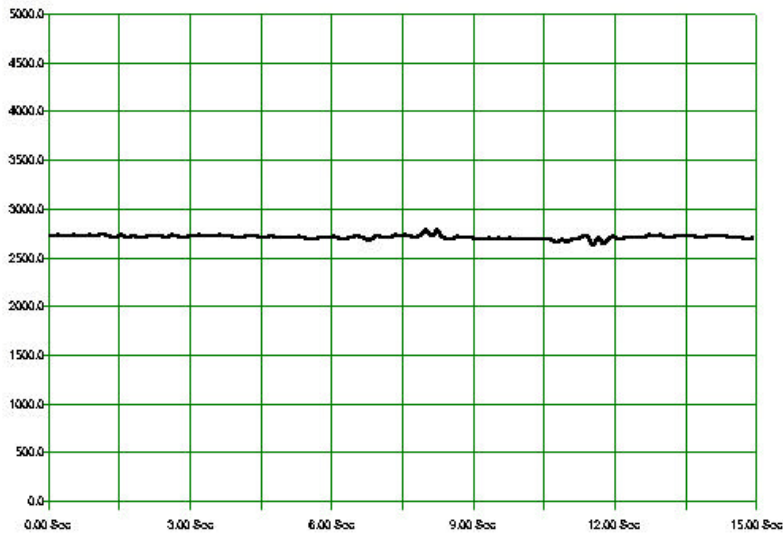
This is all awfully confusing the first dozen or so times around, so hit the library. Any physics book or chemistry book should help you. I suggest trying quite a few, until you find an author that suits you. Feynman’s Lectures on Physics is always a popular choice. But once you understand the process, 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.



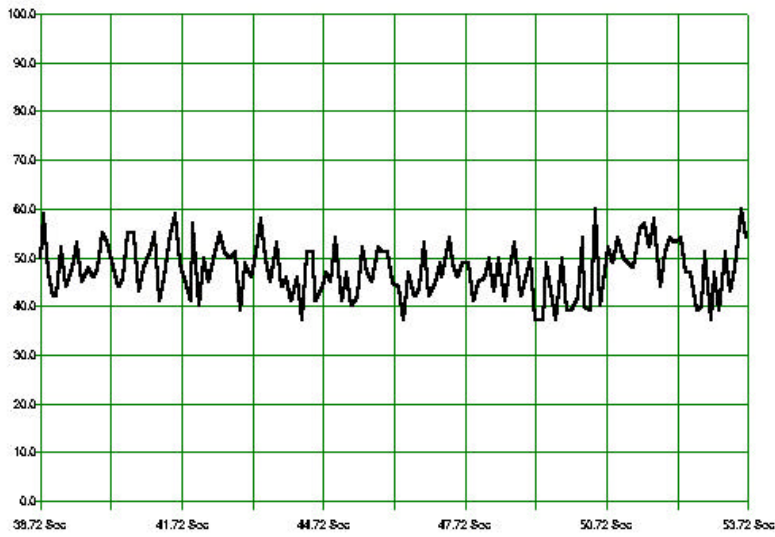
Computer Monitor (0 cm range, .01s intervals)



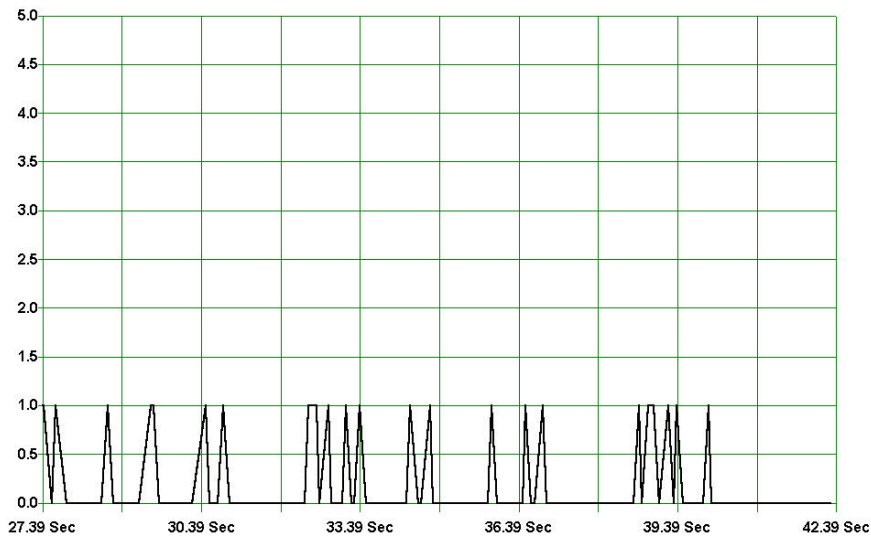
Laser Pointer
(Point blank range, .01s intervals)



Flashlight
(0cm 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 experiments to try:

1. For a finger-cuff type blood absorbency monitor, find a light source that offers very little fluctuation (less than 2 parts per period or so). 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 or dispersed 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, but not attached to the servo, secure a diffraction grating. Put everything in a small light-proof box with a thin razor slit on the end with the diffraction grating. You can then point the contraption at a uniform gas source and perform some 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.
5. Light bulbs and many other sources (other than lasers) are known as isotropic emitters. They emit light equally in all directions at once. The source only has so many photons it can emit at any one time, and as you move away from the source, they spread out from each other. See if you can't develop an experiment to relate the distance from a source to the irradiance at that point.