All Things Digital

Amateur Radio for the 21st Century

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THE ARDUINO UNO MCU: PART DUO

Note: Part Uno appeared in TCA Nov-Dec 2014. The project concepts, information and procedures are from the RadioShack Sun and Sky (S & S) Monitoring Station kit and manual designed by Forrest Mims III (see Figure 1). Forrest was kind enough to answer my questions as was his cohort Dr. David Brooks (PhD).

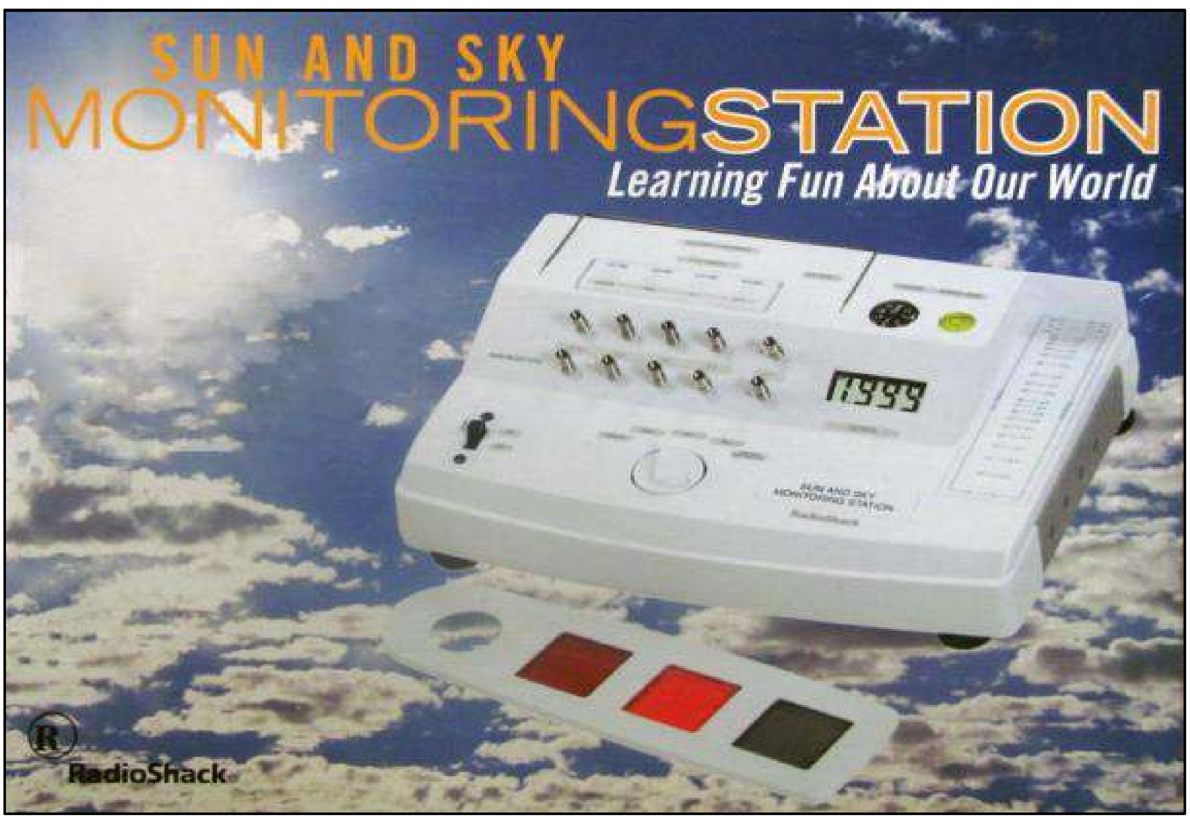


FIGURE 1: RADIOSHACK SUN AND SKY MONITORING STATION

THE PROBLEM WITH PROJECT UNO

Astute readers probably noticed a problem with the green LED radiometer's sunlight measurements. The no-load (non-proportional) voltage very quickly settled at a constant level and varied very little unless clouds blocked the sun, and what was actually being indicated was the average percentage of the green light spectrum, but we can't determine this value without also measuring the red and blue spectra for comparison.

When LEDs are used as light sensors, they produce a miniscule "leakage" current directly proportional to the light intensity but it flows in the opposite direction of "normal" current so we need to "force" the current through a load resistor (220 to 470 ohms works well) so we can measure the voltage and/or power produced ($\mathbf{E \propto IR}$ and $\mathbf{P \propto I^2R}$) to compare this against other atmospheric values defined in terms of volts and watts, but this only produces very, very small voltages that the Uno simply can't measure with its 10-bit ADC (analog-to-digital conversion) and 4.88 millivolts (mV) sensitivity so we need to "pump it up" using current-to-voltage (transimpedance) amplifiers and 16-bit with 76 microvolts (uV) sensitivity.

COLOUR TO DIGITAL LIGHT SENSOR MODULES

Fortunately, many electronics companies have developed inexpensive, software controlled, self-contained surface mount technology (SMT), red, green, blue and clear [white or all-spectrum]) RGBC 16-bit ADC colour to light sensor boards allowing allow us to detect, measure and analyze any light source (sun, moon, planets, stars, LEDs, CF bulbs, etc.) and this is all possible because all visible [white] light is composed only of the three primary colours: red, green and blue!

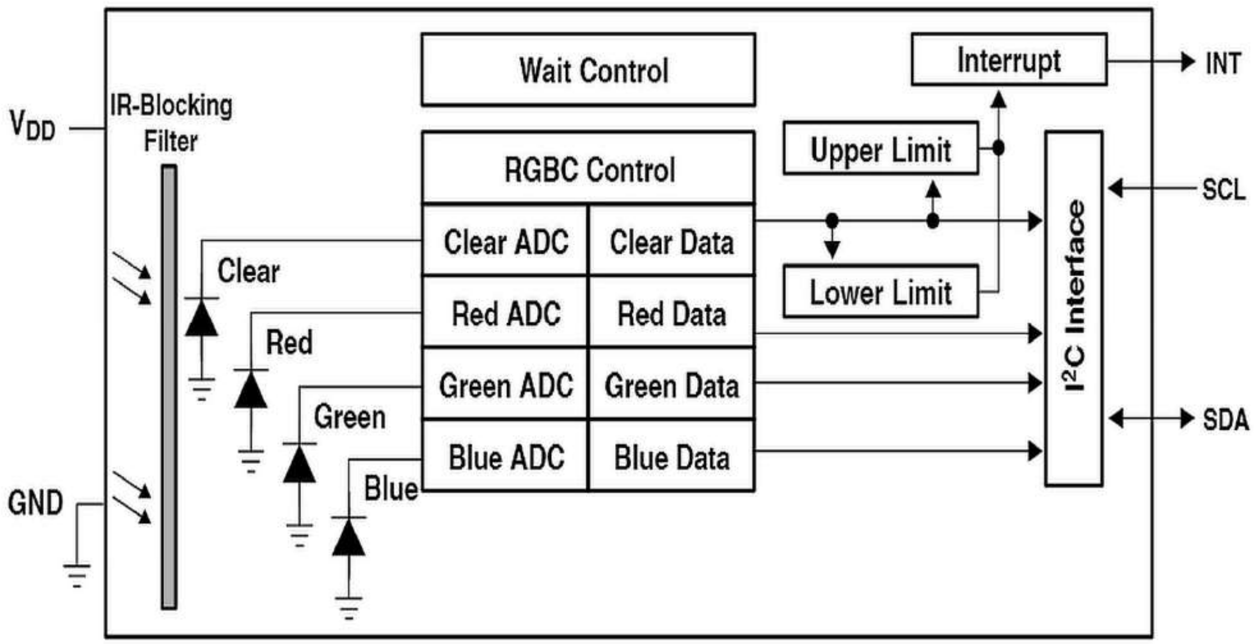


FIGURE 2: TCS34725 RGBC SENSOR BOARD

Adafruit makes a really neat module built around the AMS (formerly TAOS) TCS34725 RGBC chip (see Figure 2) with an IR-blocking filter so it “sees” light just like we and digital cameras do plus the board has built-in inter-integrated circuit (IIC, I2C or I^2C) support so we only need two analog pins to transfer data from the four LED’s. The support code library does all the work to control the sensor, break up light into its component RGB and Clear values, calculate the proportional voltages, correlated colour temperature (CCT) and photometric lux [light] level from which we can calculate other things like the approximate radiometric insolation.

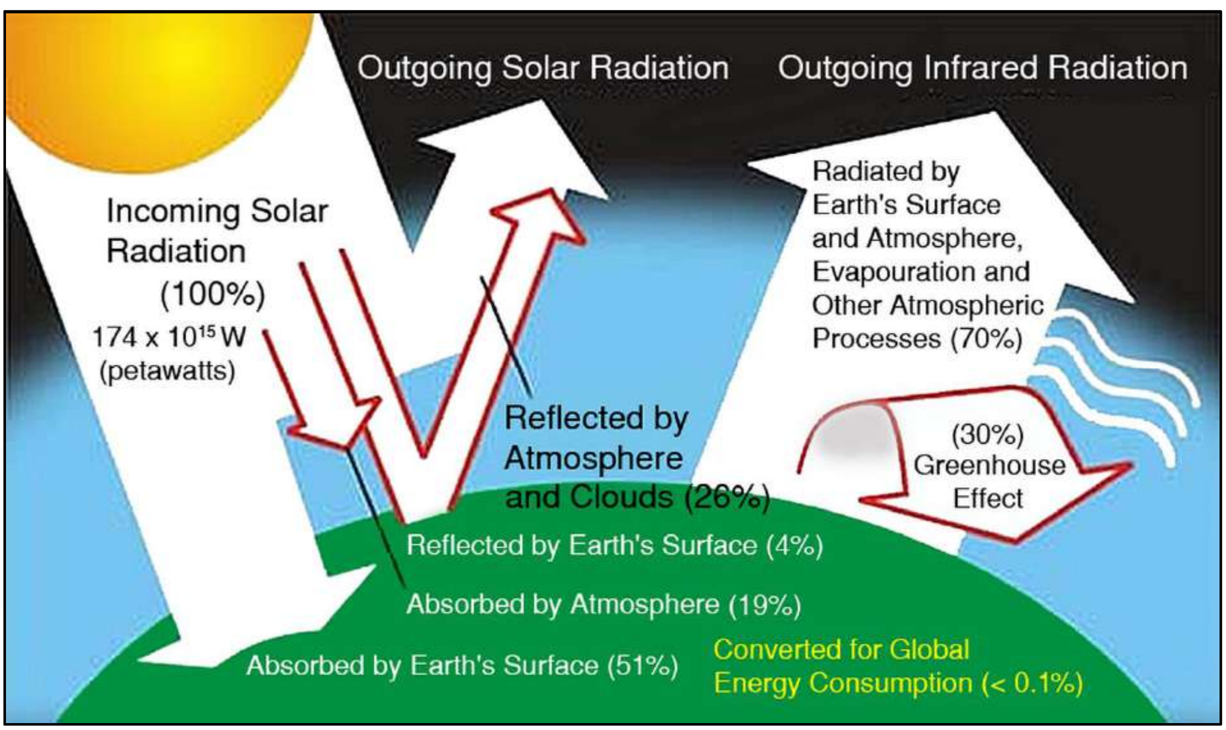
INSOLATION: THE NOT SO CONSTANT, SOLAR CONSTANT

Insolation (Latin: insolare “to expose to the sun”) is the sunlight energy or irradiance (radiation) the earth receives from the sun. In just one hour, the earth absorbs more free solar energy than all the world’s other energy resources combined can produce in one year, yet we globally “harvest” less than 0.1% of this totally “green” energy source!

But insolation isn't quite a constant "constant" because there are seasonal and north/south hemisphere variations caused by the earth's elliptical orbit and axis tilt, as a result, the southern hemisphere is slightly closer to the sun during their summer (our winter) resulting in higher exposure to ultraviolet (UV) radiation and heating effect than experienced in the northern hemisphere. Recent satellite data indicate insolation is also affected by the solar cycle and its cyclic variations of 11, 88, 208 and 1000 years and the solar cycle (as of 2015) seems to be entering a "slowdown" possibly mimicking the Dalton Minimum [1790-1830].

The solar constant [insolation] is defined at the top of the atmosphere as a mean value of 1361 watts per square metre (W/m^2) based on the latest satellite telemetry (reduced from 1366 W/m^2). On the equator, using a standard atmospheric model with a clear sky at solar or local noon (when the sun is at its zenith or highest point in the sky), the mean surface insolation is defined as 1000 W/m^2 measured perpendicular to the earth's surface (cosine function), but as you move farther north/south of the equator the surface insolation decreases because the sun doesn't rise as high in the sky.

FIGURE 3: INSOLATON AND THE GLOBAL ENERGY BALANCE



Amazingly (see Figure 3) all of the sun's incoming daytime insolation is balanced by the earth emitting this absorbed energy as IR radiation at night (radiation cooling) with about a third reflected back by the "greenhouse" effect (the average surface temperature would be -18 degrees Celsius without this effect!). So some global warming is necessary for life to exist on the earth, but it's a delicate seesaw balance scale that we are starting to unbalance by producing greenhouse gases that can't be absorb by the atmosphere without heating things up and affecting global weather patterns. Insolation is also a very good number to know for anyone who uses/designs solar panel main/backup electrical power systems and especially if used for Amateur Radio emergency communications (EmComm). Natural Resources Canada produces photovoltaic (PV) potential and solar resource maps with instructions on how to properly adjust/position solar panels to maximize conversion of insolation to electrical energy.

THE IMPORTANCE OF BEING EARNEST ABOUT COLOUR

The sun's visible light spectrum shaped the human eye's evolution (see Figure 4) and its rods and cones are more sensitive to blue and green but less sensitive to red which explains why red light doesn't affect our night adapted eyesight and why we don't have IR vision, but we can and do use IR-based devices for short range remote control, optical communication, heating/cooking, non-contact thermometers, weapon systems and search and rescue (looking for/tracking heat signatures), etc.

Our eyes are very susceptible to the "blue light hazard" (photochemical oxidation) which is the process which darkens my Transition eyeglasses outdoors even when it's cloudy. Reflective surfaces like snow, water, ice and white sand are even more problematic because they reflect light at all angles at us and can nearly double the UV and blue light intensity! Our retinas have no pain receptors to let us know "Enough already!" and over-exposure can easily go unnoticed until sun and/or flash burn occurs so proper eye protection is just as important as skin protection whenever you go outside—even in the winter.

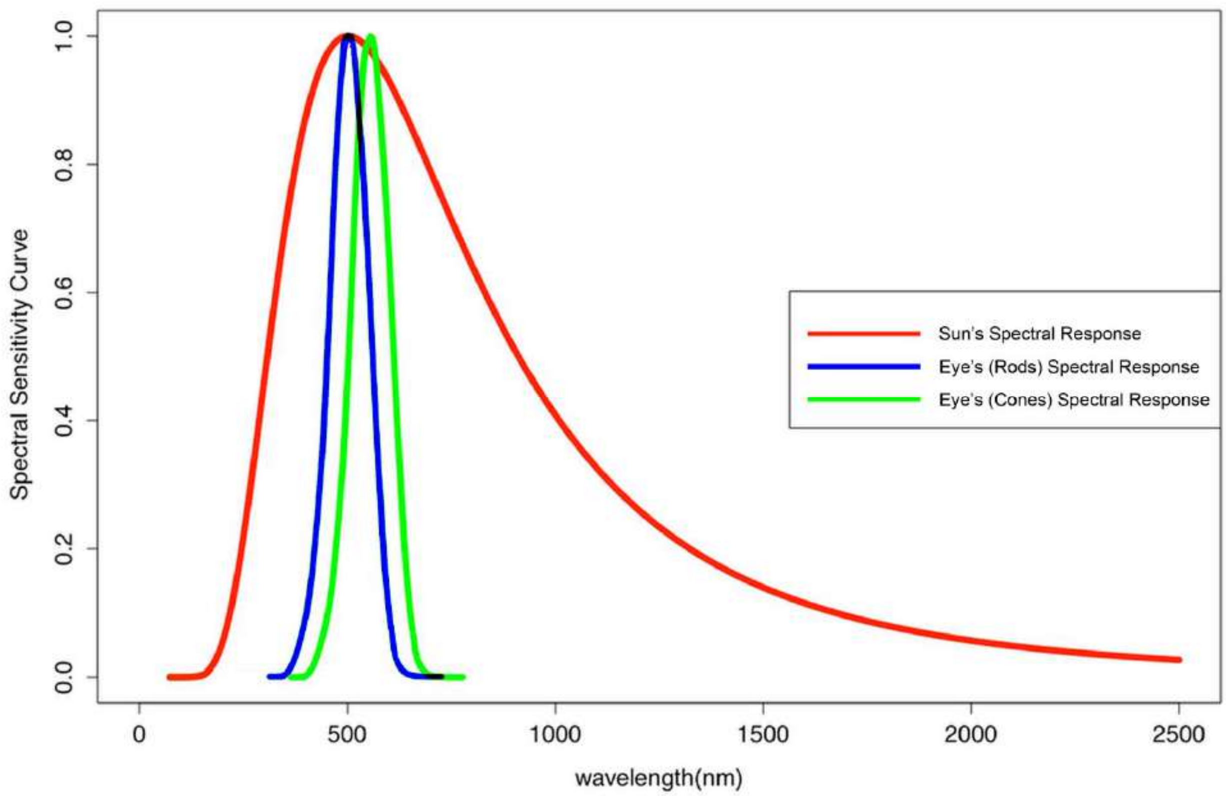


FIGURE 4: SOLAR/VISUAL SPECTRAL RESPONSE CURVES

Flora (plants, flowers, trees, et al) and oceanic algae use the greenhouse gas carbon dioxide (CO_2), water and sunlight (mainly the blue and red spectra) for photosynthesis (conversion of light to chemical energy) producing and releasing oxygen into the atmosphere at just the right percentage (about 21%) for we air breathers, but global warming is affecting this balance and it's estimated that oxygen (O_2) levels have been dropping steadily and accelerating faster since 2003 as a result of our greenhouse gas emissions so now the O_2 level is decreasing faster than the CO_2 level is increasing which means that we'll probably run out of a breathable atmosphere well before global climate change adds final insult to injury!

PROJECT DUO

This combination radio/photometer gadget (see Figure 5) breaks down any light source into primary colours and produces proportional voltages from which we can calculate colour percentages, CCT, wavelength, lux and approximate insolation, etc.

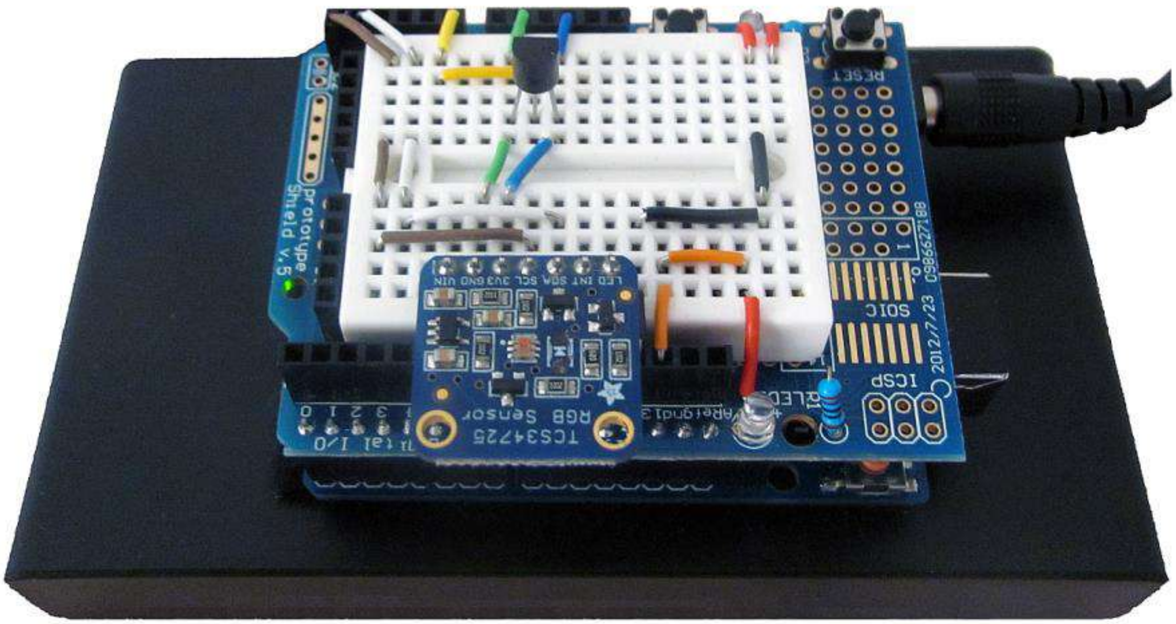


FIGURE 5: PROJECT DUO GADGET WITH BATTERY PACK

Clouds, fog, precipitation, haze, smoke, smog, terrain, trees, buildings, time of day/year and latitude all affect the sunlight reaching our sensor, and recording weather and sunlight data over days, weeks, months and years builds a profile you can use to detect any dramatic atmospheric and/or climatic changes in your area. An external TMP36 analog ambient air temperature sensor (optional) or an UV sensor (optional) can be added to the gadget (I opted for the ML8511 UV sensor in a later design). The Uno's MCU internal 1024-byte electrically erasable programmable read-only-memory (EEPROM) is used as a simple data-logger so we can disconnect our computer and put the gadget (with a battery pack) in a convenient location where it can silently sit and do its job collecting data (just over 21 hours) which is later extracted and imported into a spreadsheet for analysis (see Figure 6).

FIGURE 6: SAMPLE SENSOR RESULTS

Parts List

1. Arduino Uno (USB B cable, computer and programming software).
2. Arduino prototyping shield with solderless mini-breadboard and assorted #22 wires/jumpers.
3. Adafruit TCS34725 RGBC colour to digital light sensor board.
4. TMP36 analog temperature sensor (optional).
5. Project Duo sketches and logging spreadsheet (from my website).

The circuit is very easy to build on an Arduino prototyping shield (daughterboard) that mounts on top of the Uno MCU which supplies the power and control. Once everything's working properly, you can remove the breadboard and build/solder the circuit directly onto a copper PCB (printed circuit board) prototyping shield using whatever construction style you prefer (point-to-point, Manhattan, ugly [dead] bug, et al).

The gadget is used indoors in the same way as the Project Uno gadget; for outdoor use, you'll need a weatherproof, clear container (plus diffuser) with some kind of level mounting attachment to secure it to a post and keep it in consistent sunlight conditions during daylight hours (as is practicable). *Note: Detailed construction, schematic and operating instructions plus additional information and support documents are available on my website.*

MY FINAL

For Hams "into" meteorology and/or climatology, the use of simple LED-based atmospheric measuring devices can enhance your knowledge and enjoyment, plus contribute useful data for others by sharing data through the Internet.

In my next column we'll build a simple Arduino Uno direct conversion receiver (DCR) whose output is processed by software to decode various digital data modes.—73

REFERENCES AND RESOURCES

Adafruit
https://www.adafruit.com

Arduino
http://arduino.cc

Atmospheric and Solar Data
http://www.gaisma.com/en
http://tinyurl.com/23lrl8c

David Brooks, PhD
http://www.instesre.org

Forrest Mims III
http://tinyurl.com/3woj7t4
http://tinyurl.com/nvulko5

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http://www.introtoarduino.com

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VA3ROM: All Things Digital
http://tinyurl.com/og2acxq