PROTOTYPING A MINI-RADIOMETER FOR MEASURING REFLECTED LIGHT FROM DIFFERENT TYPES OF LAND COVERS

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Abstract: *In this paper, we describe in detail the prototyping of a mini radiometer for spectral data measurements. It is based on three main parts:* ***-1-*** *an RGB + near-infrared leds for the emitted light and a photodiode for the reflected light.* ***-2-*** *An 8-bit microcontroller for automatic data acquisition, calibrating and storing.* ***-3-*** *A user interface with small keypad + LCD display. An optional serial link interface is also provided for a compatible PC/Windows platform, with an open source C++ application software, in order to handle and deal with the mass of data collected. This instrument is useful for measuring the spectral reflectance of different land covers, in the visible and near-infrared wavelengths, to allow the construction of a characteristic curve named spectral signature of the object. The study of spectral signatures for different types of surfaces such as water, bare ground or vegetation (to name a few) allows their automatic identification by remote sensing, as done, for instance, by the NOAA satellite system, using the AVHRR (Advanced very High Resolution Radiometer) data sensor of the freely distributed HRPT (High Resolution Picture Transmission) images.*

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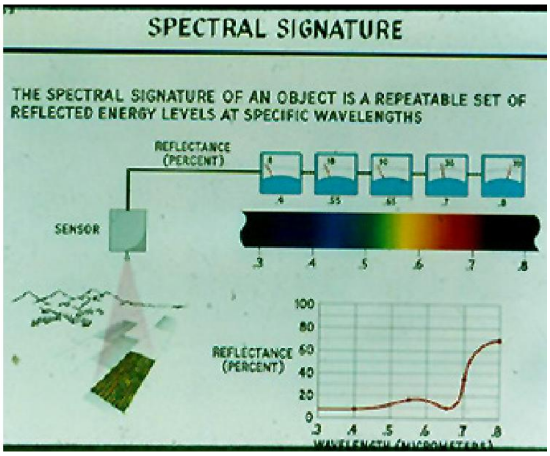
Key words: Radiometer, Reflectance, Spectral signature, Remote sensing, Microcontroller.

1. Introduction

Most remote sensing data consists of receiving and measuring reflected and/or emitted radiation from different parts of the electromagnetic spectrum. Those parts of the spectrum most commonly sampled are the ultraviolet, visible, reflected infrared, thermal infrared, and microwave segments. Multispectral band consist of radiation collected over sets of electromagnetic radiation that individually extend over (usually narrow) intervals of continuous wavelengths within some part of the spectrum. Each interval makes up a band or channel identified by a color (if in the visible), a descriptive label (e.g., Near IR), or a specified range of wavelengths. The data are utilized by computer-based processing to produce images of scenes (Earth's surface and atmosphere; planets; cosmological features) or to serve as digital inputs to analytical programs. Multiband images collected by one sensor will usually show notable differences from one band to the next. This is because the radiation from point to point in an array of sampling areas making up a scene will vary depending on the reflectance or remittance response of the various features/materials are different within an interval, and different again when other bands are examined. The band to band response (in terms of magnitude or intensity of radiation) of any such point can be connected to become the spectral signature for a given feature or class of materials. Different features/classes have differing and normally distinctive signatures. **[1]**



SPECTRAL SIGNATURE

THE SPECTRAL SIGNATURE OF AN OBJECT IS A REPEATABLE SET OF REFLECTED ENERGY LEVELS AT SPECIFIC WAVELENGTHS

Fig.1.A simple configuration for reflectance measurements.

While it is now possible for a sensor system to almost duplicate the spectral signature using the mode called hyperspectral remote sensing, which is a better mode to precisely identify objects, it is still, however, sufficient to deal with a crude approximation of the spectral signature composed with a smaller set of mulspectral bands, in order to distinguish some natural objects in a satellite image. **[2]**

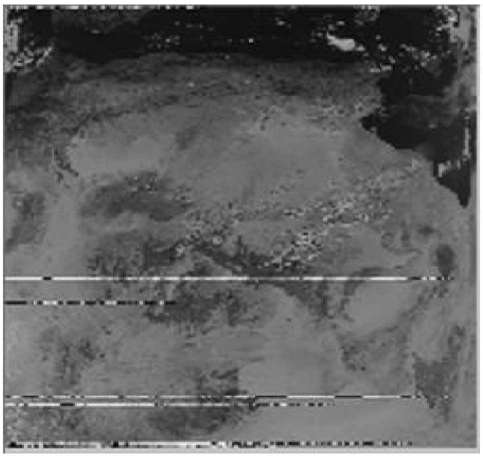


Fig.2. A satellite image from NOAA_HRPT.

2. Reflectance

Clear glass is used to cover the downward facing sensors. It is assumed that the surface from which the reflectance is to be measured exhibits lambertian reflectance properties. The reflectance R of a surface is defined as the quotient between the reflected radiation and the total radiation received:

$$R = \frac{\text{reflected Energy}}{\text{incident Energy}} \qquad (1)$$

As the amount of radiation reflected from the surface will always be less than or equal to the received energy, R has values between 0 and 1. We will express the reflectance value as a percentage (%).

$$R\% = \frac{\text{reflected Energy}}{\text{incident Energy}} * 100 \qquad (2)$$

R is a characteristic of the medium, which we use as a basis for the recognition of different materials. It depends on the wavelength R (λ). **[3]**

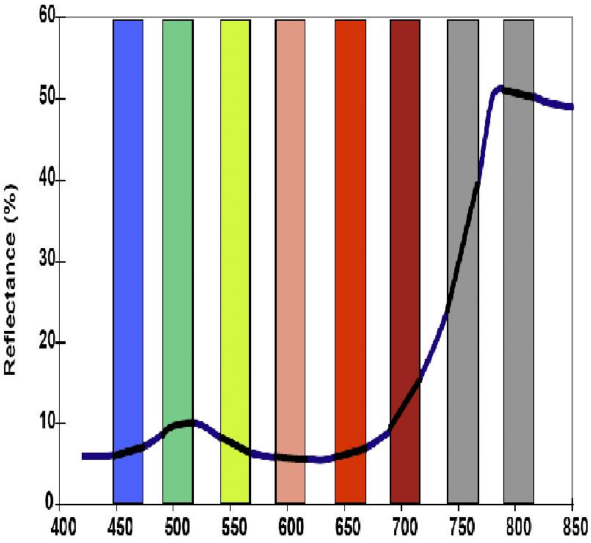


Fig. 3. A typical green vegetation reflectance spectrum.

3. Principle of the radiometer

Spectroradiometers are the most ideal devices for measuring spectral energy distribution of the light source, which determine not only the radiometric and photometric quantities, but also the colorimetric quantities of light. These instruments record the radiation spectrum of the light source and calculate the desired parameters, such as chromaticity and luminance. Dispersion of light is usually accomplished inside the spectroradiometer by means of prisms or diffraction gratings. **[4]**

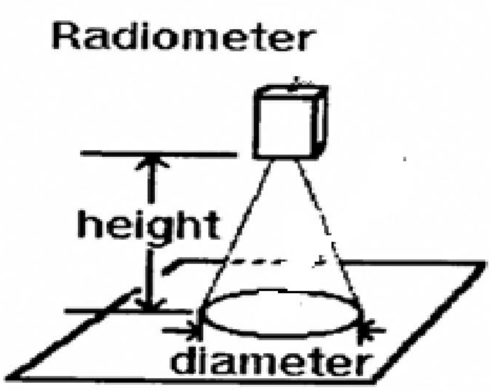


Fig.4.A functional scheme of a radiometer.

Each detector receives, through an optic and a number of mechanisms, the energy E(ω, t, λ) with measurement spectral response R (λ) and integrated over a solid angle $\Delta\omega$, during an integration time At, and spectral band $\Delta\lambda$.

4. Prototyping a mini radiometer

Through the increasing use of microcontrollers in all the domains of modern electronics, we now observe the emergence of very compact devices, with very low power consumption, and a multitude of useful internal modules available. In the field of instrumentation, the multi-spectral measurement systems, called "radiometers", were highly profitable of this fact. Thus, we can now design a mini radiometer with smaller footprint, longer battery life, higher storage capacity (in Gigabytes), multi-channels, and many other options easily programmable with a high-level language. The following mini radiometer is based on a microcontroller PIC16F785 **[5]**. It is an 8-bit mid-range microcontroller from Microchip, which contains two integrated operational amplifiers particularly useful in our case, as we need to amplify the reflected light received on the photodiode through a classic circuit called I to V converter. Figure 3 and Figure 4 show the main parts and components in the conception of this device.

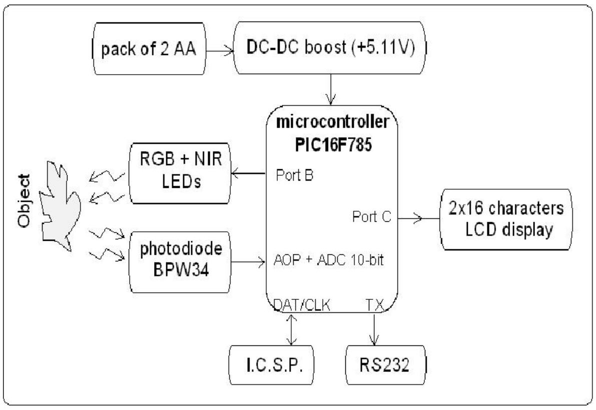


Fig. 4. Synoptic of the mini-radiometer, based on a microcontroller PIC16F785.

(RGB + NIR) leds BPW34 photodiode PIC16F785

Figure 5: The critical components involved in this design.

This low power device is fed with a battery pack of two AA, followed by a dc-dc boost converter voltage regulator to provide a stable output of +5.1V. This converter circuit is based on the MCP1640 **[6]**, a synchronous boost voltage regulator, with a typical efficiency up to 96%, impossible to obtain with a series voltage regulator (even an ultra LDO type). Another interesting feature is its capability to remain functional until battery pack drops under 0.35V !

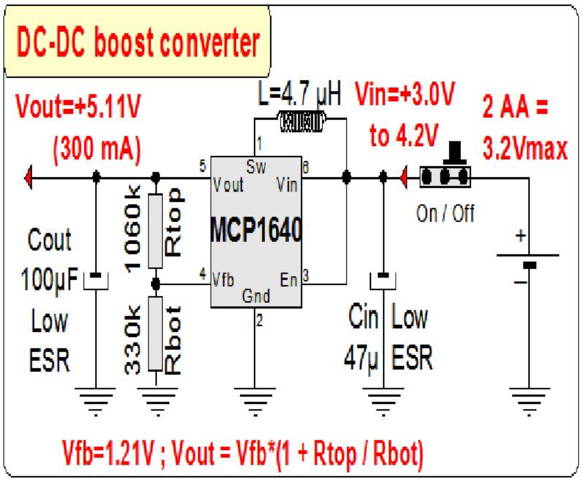


Fig.6. A dc-dc boost converter used as the power supply unit.

The microcontroller is internally clocked at 4MHz. To meet the requirements of the 10-bit internal analog to digital converter (ADC), the measurements of the reflected light from diverse sources (RGB + near infrared leds) with a photodiode, need, at least, one operational amplifier configured as a current to voltage converter [7]. We have chosen only one photodiode (the BPW34 [8]); even in the visible spectrum, its sensitivity is better than the recommended and popular photodiode BPW21, as easily noticed in the following figure 7.

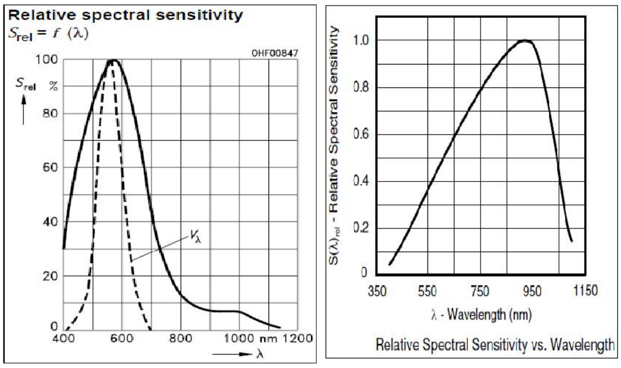


Fig. 8. Comparison of the spectral sensitivity:
BPW21: 10 nA/Lux @ 550 nm (falls to 3 nA/Lux @ 400 nm, and 7 nA/Lux @ 660 nm)
BPW34: 75 nA/Lux @ 900 nm (falls to 7.5 nA/Lux @ 400 nm, and 45 nA/Lux @ 660 nm)

Each time a light is emitted, one or two LEDs are activated, and we notice a sag voltage across the power supply, which causes some instability when reading the 10-bit measure. To minimize this effect, the internal A/D conversion is performed in sleep mode (thus eliminating much of the internal switching noise, and the microcontroller consumes the least amount of current). A schottky diode D1 has been inserted between Vout ("noisy" power supply) and Vdd ("clean" power supply).

The LCD display module requires a minimum of 10 Input/Output lines to be connected to a microcontroller **[9]**, in 8-bit mode, or only 06 Input/Output lines in 4-bit mode; therefore, this last mode was chosen to minimize the number of I/O lines. We further reduced this minimum value to 5 lines only, using a programming trick **[10]**. The input pin EN of the LCD display is driven directly by the output pin RB7 of PIC16F785, while the input pin RS of the LCD display is also driven by the output pin RB7, but indirectly, through an RC low-pass filter. If the output RB7 exceeds the time constant of the filter (R9*C3 = 10k*5.6nF = 56 microseconds), then the input RS of the LCD sees a high state (this indicates that the D4 to D7 inputs of the display LCD receive a data), otherwise, RS remains in a low state (indicating that D4…D7 inputs receive a command). This solution was possible because the EN input is only sensitive to a falling edge transition, while the RS is driven by stable logic states (0 or 1).

This device can be directly connected to any PC through the serial port by using the RS232 protocol (8N1 at 115200 bauds) without using the typical conversion circuit MAX232. As noticed in a modern PC, the serial port is sensitive to level voltages as low as 3V (in absolute value). A simple terminal software was used in order to visualize the acquisition of the measures through this connection. An optional wireless solution is also provided which consists of using a low cost BlueTooth module (compatible HC-06), and the real time acquisition data may be displayed on any android device (smartphone, or tablet, using a terminal application). The following figure shows the detailed circuit of the mini-radiometer.

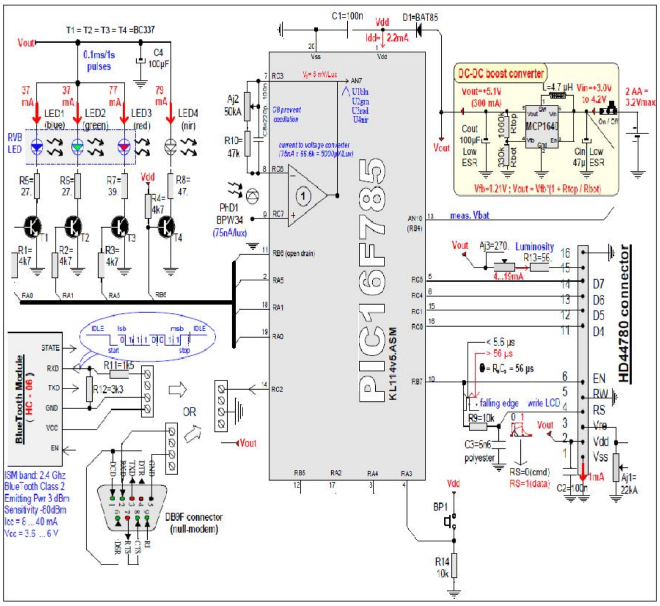
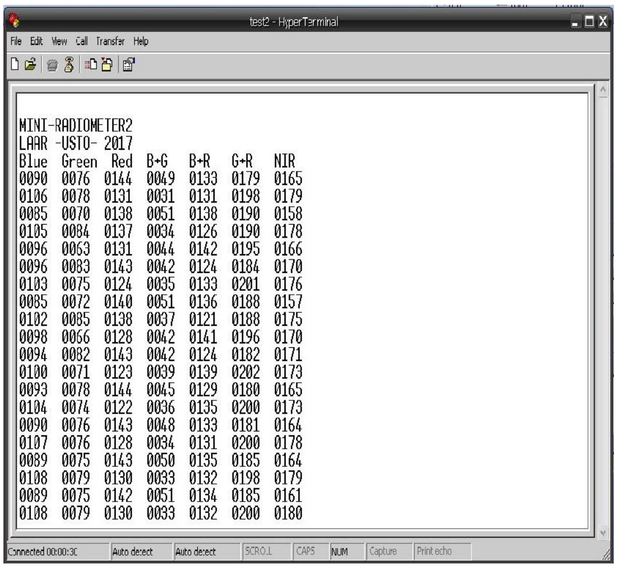


Fig.9. The detailed circuit of the mini-radiometer based on a PIC16F785



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MINI-RADIOMETER2
LAAR -USTO- 2017
Blue  Green  Red  B+G  B+R  G+R  NIR
0090  0076  0144  0049  0133  0179  0165
0106  0078  0131  0031  0131  0198  0179
0085  0070  0138  0051  0138  0190  0158
0105  0084  0137  0034  0126  0190  0178
0096  0063  0131  0044  0142  0195  0166
0096  0083  0143  0042  0124  0184  0170
0103  0075  0124  0035  0133  0201  0176
0085  0072  0140  0051  0136  0188  0157
0102  0085  0138  0037  0121  0188  0175
0098  0066  0128  0042  0141  0196  0170
0094  0082  0143  0042  0124  0182  0171
0100  0071  0123  0039  0139  0202  0173
0093  0078  0144  0045  0129  0180  0165
0104  0074  0122  0036  0135  0200  0173
0090  0076  0143  0048  0133  0181  0164
0107  0076  0128  0034  0131  0200  0178
0089  0075  0143  0050  0135  0185  0164
0108  0079  0130  0033  0132  0198  0179
0089  0075  0142  0051  0134  0185  0161
0108  0079  0130  0033  0132  0200  0180
```

Fig .10. A screenshot from hyperterminal application to monitor the reception of the measures through the PC serial port.

Fig.11.A preview of the miniradiometer prototype, using an optional low cost BlueTooth module, to monitor the acquisition data through an Android device.

5.Measuring the reflectance of different materials

The following natural objects (dry sand, humid sand, green leaves, dead leaves) have been chosen for the measurements. The reflected light from each sample is first measured as a voltage, after converting the 10-bit digital count (between 0 and 1023) indicated by the microcontroller. Some combinations with the red, green and blue light, from the RGB led, give us three others lights (cyan, magenta and yellow). Adding the near infrared red allows us to plot the spectral signature for each sample with 7 measures.

The operation has been repeated for different samples as mentioned below; each spectral signature is represented in the following chart with a different color:

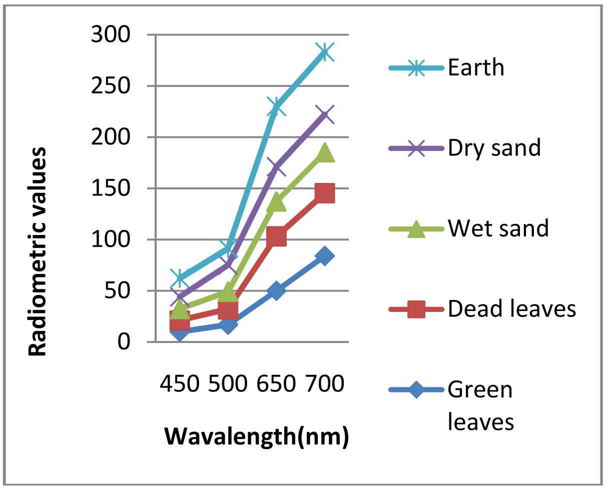

Fig.12. Spectral measures for some natural objects.

6. Conclusion

In this paper, we have described a simple circuit to prototype a mini radiometer, based on a cheap microcontroller. We have been particularly interested by the visible and near infrared spectrum. So, this device monitors the radiated light through a specific RGB led in the visible spectrum, and a near infrared led. The reflected light is then measured through a classic I to V converter circuit, with an operational amplifier integrated in the microcontroller. A significant level response is then obtained with the internal 10-bit ADC converter.

References

References should appear in a separate reference section at the end of paper with items referred to by numerals. They should appear in the chronological order in which they are cited. No parentheses or brackets will be used. Books (monographs), journal articles and conference papers will be cited different and accordingly.

Monographs (books) will be referred to by the surname and the initial(s) of the author(s)' first name(s), original title (followed by the English translation between parentheses), both title and translation italics, followed by indication of publisher, place and year of publishing. Example:

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