Opacity Measuremen

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Opacity is a measure of impenetrability of objects or substances to radiation. Here, we are concerned with light, specifically within the spectrum visible to the human eye. In this month's instalment of the Modding & Tweaking series, we examine how the PC can do paper opacity measurements for us — all experimentally and on a budget of course!

The (simplified) relative sensitivity curve of the human eye shown in **Figure 1** tells us that he eye is more sensitive to green light than to yellow.

In order to be able to measure the visual opacity we ideally need a photodetector whose spectral sensitivity is similar to that of the human eye. A commonly available photodetector like the BPW34 has good sensitivity within a part of the spectrum perceived human eye, although its response curve is dissimilar, see **Figure 2.**

The response also depends on the type of light with which the object is illuminated. If we use a yellow LED we can look forward to an emission distribution roughly as in **Figure 3.**

The use of a yellow LED as the light source causes the detector to see the yellow part of the spectrum only, resulting in a better approach of the spectral response of the human eye. The comparison is illustrated by the graphs in **Figure 4** and **Figure 5**. Possibly, the use of mixed yellow and green light is even better although the results with yellow only are quite good.

The electronics

The opacity meter is based on frequency variation obtained from an oscillator that's controlled by the intensity of light detected by a BPW34 photodetector. **Figure 6** shows the schematic. The oscillator consists of a NAND gate from a 4093 package. Its frequency (10-100 Hz) is determined by C3 and R3, together with preset P1 and the BPW34 (D3) in the feedback circuit. The 'LCO' (light-controlled oscillator) output signal is digitized by three more gates from the same IC. The oscillator and the LEDs (one yellow, one red) are powered by a voltage regulator around a 7809. The red LED is an on/off indicator and helps to position the reader unit over the paper surface.

The circuit of the PC interface is shown in **Figure 7**. The interface with the computer is by means of the Centronics port and a series of optocouplers; four in the PC817 chip of which three are used. The connections between the circuit and the LPT1 ('parallel printer') port on the computer are as follows:

Circuit terminal	Pin no. on DB25
E1	1 (/STR)
E2	2 (D0)
E3	3 (D1)
GND	25 (GND)

The oscillator output signal enters the interface at J1. The circuit charges a 47 μF tantalum electrolytic capacitor (C1) to about 4.5 V, at which level zener diode D2 starts to pass current, illuminating the LED in optocoupler IC2. This causes a logic Low at E1, signalling to the program running on the computer to stop counting. The process comprises the following phases.

1. By means of a High level supplied to input E2, the PC effectively blocks the arrival of oscillator pulses.

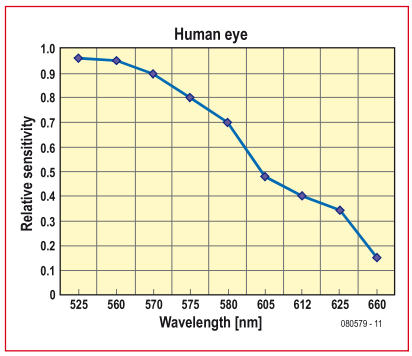

Figure 1. Plot human eye sensitivity as a function of light wavelength and you get a graph like this.

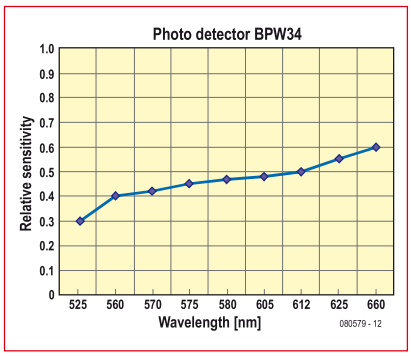

Figure 2. The response of the BPW34 within the spectrum seen by the eye is by no means flat.

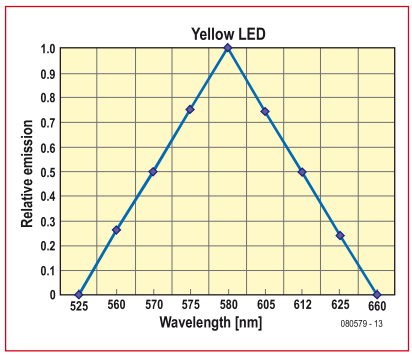

Figure 3. Heavily simplified spectral distribution of light emitted by a yellow LED.

t by PC

2. With C1 discharged, output E1 is held High i.e. deactivated.

3. Via E2, the software enables the arrival of oscillator pulses again.

4. The period it takes for the capacitor to charge to 4.5 V and pull E1 Low represents a time T, which is compared to a table entry in the program in order to determine the relative opacity value.

The value so obtained will be a reasonable approach of the actual opacity in the majority of cases. The table stored in the program is calibrated for values of opacity between 78 and 92%.

Software

This series of articles being free from rocket science, the very simplest form of Basic was used for the control program. True to the Modding & Tweaking tradition, all readers are invited to improve the program, come up with alternatives, perhaps develop code for Linux, C, 32-bit ARM platforms, what have you! Here, only the nitty-gritty is shown to serve as an incentive.
The BASIC program was written to measure, store and 'graph' instantaneous and average opacity values of paper sheets. You can download the program as file # **080579-11.zip** from the Elektor website.
The address &H378 is the base address of printer port LPT1 on the PC; &H37A is the control register at [base+2]. The first is used to send commands to the reader interface via LPT data lines D0 and D1, the second, for reading the capacitor charge status using the /STR (inverted strobe) line (which is bidirectional).

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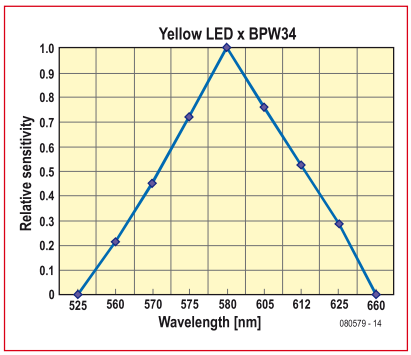

Figure 4. Response obtained from the combination: BPW34 + yellow LED.

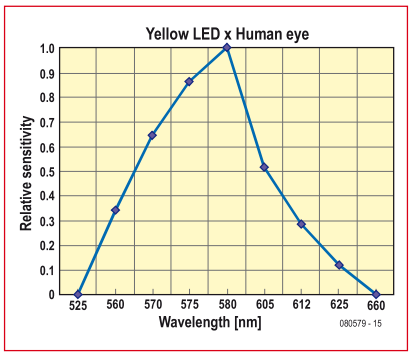

Figure 5. As Figure 4, but for the combination: BPW34 + human eye.

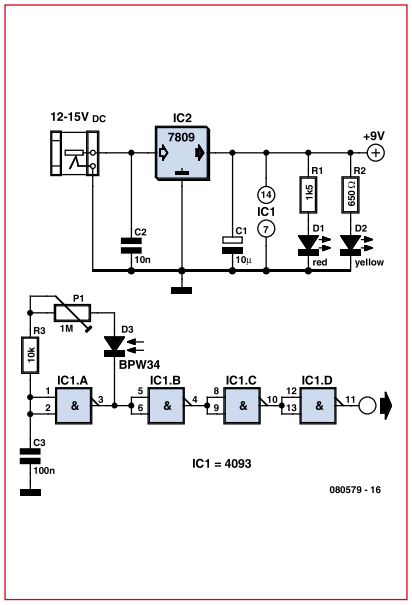

Figure 6. Schematic of the BPW34-controlled oscillator.

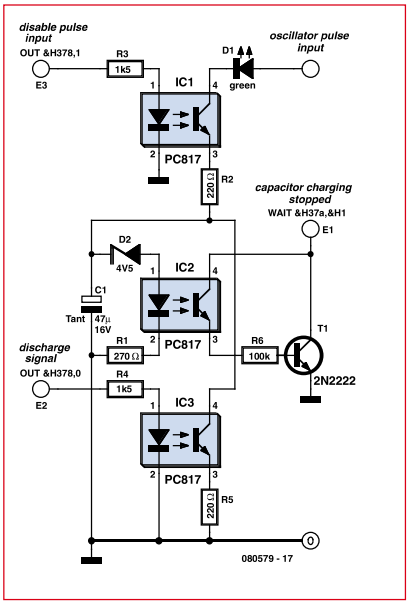

Figure 7. The PC interface consists mainly of optocouplers connected to Centronics port pins.

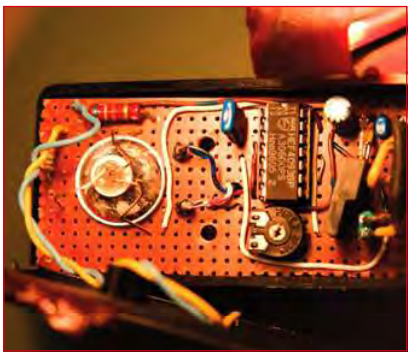

Figure 8. Internal view of the opacity reader.

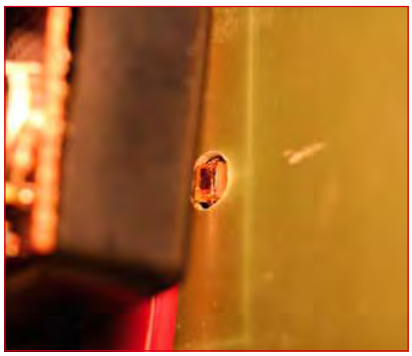

Figure 9. The face of the BPW34 photodetector protrudes from a small hole.

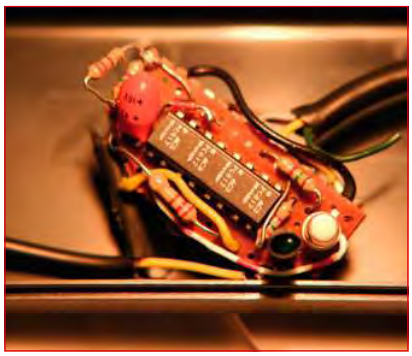

Figure 10. The PC817 quad optocoupler is by far the largest part in the PC interface.