Light Dimmer Based On Microcontroller PIC16F777

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Abstract. In the present paper we present the design and implementation of a device cappable of mantaining the level of light present in a relatively small area, such as a room or office, in a semi-constant value (ie. with variations which the human eye cannot perceive). This level of light should be defined by the user. In order to achieve this, we propose to use a microcontroller that, according to the difference between the current level of light and the desired level of light, sends a control signal which enables an artificial source of light, such as a lamp, to generate more or less ligth, depending on the cappacities of the light source. The desired level of light should be adjustable in any moment. ...

1 Introduction

The main goal of the current project is to design and implement a device which mantains constant (according to what the naked human eye can perceive) the level of light in a specific area, which is relatively small too, such as a cubicle, room, or office. The former will be achieved by modifying the level of light produced by the artificial light sources present in the area. Also, the desired level of light intended to be mantained must be modifiable by the user at any moment during the working time of the device.

The way chosen to achieve these goals is to employ a microcontroller unit of the PIC16F777 family, built by Microchip^{TM}. This microcontroller will receive data from a light sensor unit, in order to determine the difference, if any, between the current level of light and the desired level of light. With this information, the microcontroller generates a Pulse Width Modulation (PWM) signal which then transmits to a "control" device, which will then allow or disallow the pass of current to the light source according to the PWM signal. As an additional achivement, our proposal should have a low cost, every component should be relatively easy to buy, and the design should be easy to extend.

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2 Design

Given the goal of low cost, and in order to simplify and accelerate the design phase, we decided to use a commercial 12 V lamp as the artificial light source and a bipolar transistor of the TIP41C family as the controler device. For the same reason, we choose a 4 MHz oscillator, since it makes the clock cycle of the microcontroller to have a duration of 1 μs, which eases in a great measure the task of calculating times. On the other hand, we want the oscilations in light level to be undetectable by the unaided human eye. Thus, the output signal frequency, which is the frequency at which the light source will work, was restricted to a minimum of 60 Hz, which is the standard for conventional lighting. In regard to the light sensor, there are different available choices, such as digital sensors, photodiodes, phototransistors, and photoresistances. We selected a photoresistance due to its low cost and ease of implementation, both factors in which this option clearly surpasses the other options.

Now, for the microcontroller to be able to know the current level of light, it reads the signal delivered by the light sensor, which is an analog signal, and converts it into a digital value. For this purpose, the Analog–to–Digital Converter (ADC) module was used. Being a 10-bit resolution converter in the PIC16F777 family, this module delivers digital values between 0 and 1023, inclusive. In order to indicate that the lamp must generate more or less light, a control PWM signal was used. This PWM signal codes in the pulse width, how much time of a certain cycle must current be passed to the lamp. Thus, the wider the pulse, the more time is current allowed to pass and the lamp generates light during more time, while at narrower pulses, current passes for less time, making the lamp generate light during less time; and obviously, if the lamp spends more time generating light, then more light is generated. This PWM signal is generated by the PIC's Capture / Compare / PWM (CCP) module, working in its PWM mode. This module, when functioning in PWM mode, has a 10-bit resolution —ie. the Duty Cycle (DC) value of the PWM signal is given between 0 and 1023, inclusive. Thanks to that, the colaboration between the ADC and CCP modules is quite simple, since there is no need for additional manipulation of the values delivered by the ADC module, in order to make them compatible to what the CCP module can manage. The design is shown schematically in Figure 1.

Once the value representing the current level of light has been obtained, it is compared to the value representing the desired level of light. Depending on their difference, the contorl PWM signal is modified, according to the following three possibilities:

- If they are equal, the signal remains unchanged.
- If the current level is less than the desired level, the DC of the PWM signal is increased.
- If the current level is greater than the desired level, the DC of the PWM signal is decreased.

Due to the characteristics of the CCP module in PWM mode, the lowest frequency allowed by a PIC16F777 working with a 4 MHz oscillator is of

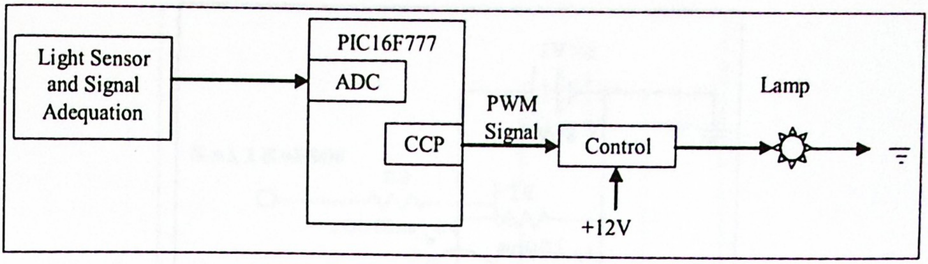

Fig. 1. Block diagram of the proposed design

244.140625 Hz, making the greatest possible PWM cycle of 4.096 ms. Given the restriction on the frecuency of the variations in the light source, established on 60 Hz as inferior limit, 244 Hz perfectly complies with it. The frequency at which the ADC module will sense the signal presented by the light sensor will be of 244.140625 Hz, and will be controled by the CCP module that generates the PWM signal. Since the variations on the general level of light will be given by the variations on the artificial and natural light ources, it is sufficient to sense the level of light at this frequency, since natural light changes at much lower frequencies and the artificial light sources will be controled by the PWM signal, which works at precisely 244 Hz. The level of light which we plan on keeping constant will be defined, originally, during the programming time of the microcontroller, at a value of 25% of the DC. However, during normal operation of the device, it will be possible to modify this value, through a variable resistance or potentiometer, which will change the voltage on a power line between 0 V and 5 V of direc current, which in turn will be converted by an ADC module (different from the one used to convert the signal of the light sensor) to a digital value between 0 and 1023 inclusive.

3 Hardware Implementation

3.1 Input: Light Sensor

As mentioned above, we decided to use a photoresistance as sensor. In this case, we specifically used a 2 MΩ photoresistance since it was the photoresistance with the smallest range we could get at the time. Given that great sensibility and accuracy are not of interest to this design, and the sensing frequency is relatively low, this photoresistance covers the requirements quite well, with the added benefits of being easy to acquire and unexpensive. Now, the signal must be prepared before delivering it to the microcontroller. For this we used a 10 kΩ potentiometer as a calibrator, which delivered a signal between 0.8 V and 5 V. Therefore, the input circuit is shown in Figure 2.

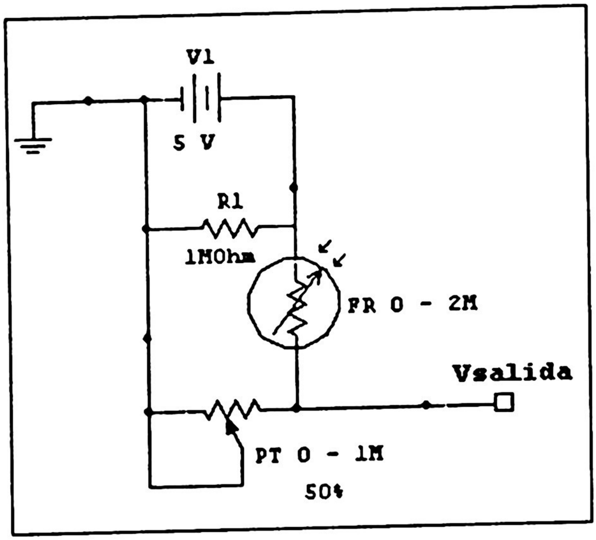

Fig. 2. Diagram of the input circuit

3.2 Output: Light Source

In order to generate the needed level of light, the PWM signal is deliverd to a "control" device, in this case a transistor of the TIP41C family. While the TIP receives a PWM signal with logical value of 1 (5 V), it will let the power signal pass to the lamp; when the value of the PWM signal changes to logical 0 (0 V), the TIP stops feeding power to the lamp. Thus, the pulse width of every cycle of the PWM signal, namely the signal's DC, determines the percentage of the time alloted by the cycle period during wich the lamp is given power. This regulates the average level of voltage delivered to the lamp in a given period of time, making the lamp generate more or less light. The resulting output cicuit is shown in Figure 3. On the other hand, Figure 4 shows the complete diagram, with both input and output circuits, along with the microcontroller and their conections.

4 Software Implementation

In order to obtain the value of the current level of light, compare it with the value of the desired level of light, and then generate the PWM signal according to the difference between both levels, the PIC microcontroller was programmed as described in the flow diagram portrayed in Figure 5.

The ADC module is configured to do the conversion as soon as possible, deliver the converted value and wait for the program to process it. On its part, the PWM module is configured to use the largest period allowed by the PIC when working with a 4 MHz: 4.096 ms. Whenever a PWM cycle ends, the updated value

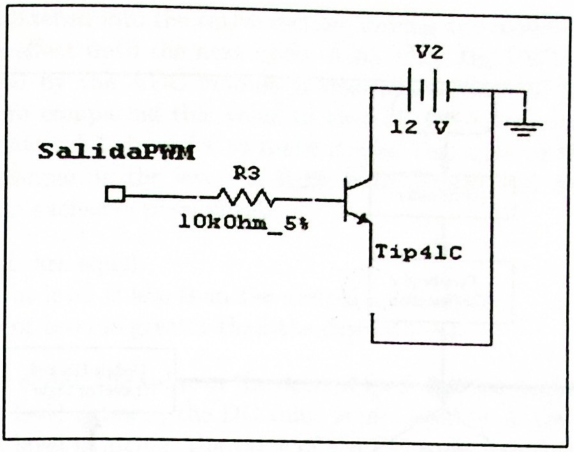

Fig. 3. Diagram of the output circuit

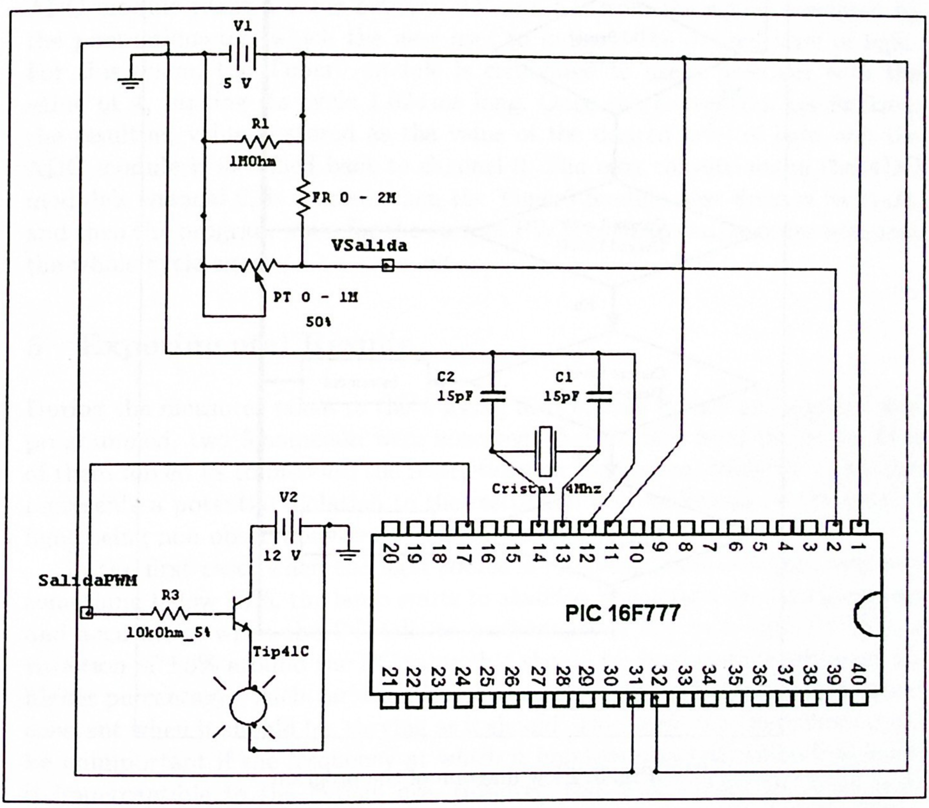

Fig. 4. Complete diagram

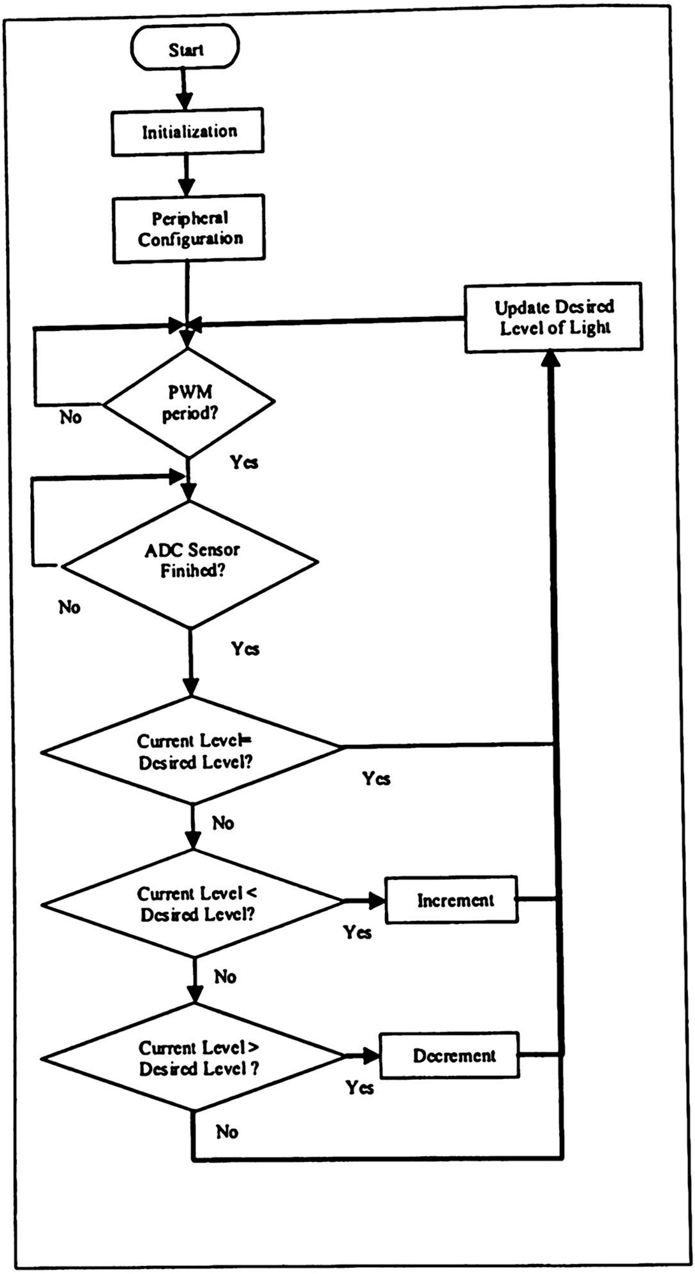

Fig. 5. Flow diagram of the program

for the DC is latched into the active section, forcing any modification to the DC value to take effect until the next cycle. Also, when the PWM cycle ends, the value delivered by the ADC module is read and written as the current level of light. Before comparing this value to that of the desired level, the ADC is switched to channel 1, in order to make it read the value of the desired level. Now, when comparing the levels of light, both current and desired, there are three mutually exclusive possibilities:

- Both levels are equal.
- The current level is less than the desired level.
- The current level is greater than the desired level.

If they are equal, the value of the desired level remains unchanged. However, if the current level is lower, the DC value is increased by 4. On the other hand, if the current level is higher, the value of the DC is decreased by 4.

After these, the Timer0 module is initialized and the program waits until it completes its cycle to start the next conversion, giving the ADC module enough time to correctly acquire the signal of the next channel. In this channel, the ADC module reads a value between 0 V and 5 V from the signal presented by the pontentiometer, which the user uses to indicate the desired level of light. For this reaon, the Timer0 module is configured to use a prescaler with the value of 4, making its cycle 1.024 ms long. Once the conversion has finilized, the resulting value is stored as the value of the desired level of light and the ADC module is switched back to channel 0. The next conversion, on the ADC module's channel 0, is started when the Timer0 module next finishes its cycle, and then the program waits for the current PWM cycle to end, in order to repeat the whole cycle again.

5 Experimental Results

During the measures taken to the working device, once it was implemented and programmed, two fenomenon were observed, that deviate from the norm. One of them forced us to increase the restrictions on the system, while the other one represents a potential violation to the restriction over variations on the level of light being non observable by the naked human eye.

In the first case, when the light source is receiveng small voltages, meaning something below 20%, the lamp starts to *shudder*. Speaking more cuantitatively and accurately, when the DC falls to percentages of the cycle below 17.5%, a variation of ±5% around the DC value that should be mantained is observed. At higher percentages, such variation is not seen, the value of DC being mantained constant when it should be, varying as it should. This deviation from norm could be unimportant if the frequency at which it happens was high enough to make it imperceptible to the human eye. However, this is not the case, since such frecuency was estimated to be close to 10 Hz; nevertheless, notice that the latter is only an estimate, given that no accurate measure was taken. In order to avoid this deviation, we decided to establish the equivalent to 17.5% of DC as the minimum allowed value for the desired level of light, thus making the available range for this values between 180 and 1023 inclusive.

In the second case, the increments and decrements on the DC have a magnitude of 4. Thus, when there is a severe modification of the desired level of light, such as going from a value of 1023 (sensed signal of 5 V) to a value of 200 in the time of a couple of PWM cycles, say les than 20 ms since one cycle lasts 4 ms, and the desired level of light remains at that second value for a long enough time, as could be 5 s, it takes close to 864 ms for the device to reach the desired DC value. The latter means that, in such an extreme situation, the general level of light would suffer a decrement for more than half a second, time enough for the naked human eye to perceive the change. A possible solution to this problem would be to alter the algorithm with respect to the magnitude of the updates to the DC value, in such way that the time needed for congruence is reduced below the ability of the human eye to detect it, at least below 40 ms, which would be equivalent to a frequency of 30 Hz. Notice, however, that this solution would make the update quite abrupt, which could in turn be undesirable. Another posibility would be to make the update smoother, by making it last longer, perhaps a whole minute, or even more, for a modification as large as that mentioned above.

6 Conclusions

In most situations, the proposed device behaves according to the established goals and restrictions, fullfiling also the objective of being a unexpenisive, easy to implement solution. However, two deviations from these norms were observed. One when the DC falls below 17.5% of the PWM cycle, and the other when the desired level of light is modified by a large amount in a short time. The first problem was solved by making 180 the lowest possible value for the desired level of light, thus disallowing the DC to go below 17.5%. The other problem has not been solved yet. Eventhough these two problems arose, they are not so bad. In the case of the shuddering of the lamp, this phenomenon ressembles a candle. We believe this should be further explored, since it could lead to a unexpensive simulation of candlelight, whithout having to replace the light sources, only installing the device.

Some improvements and future work on the porposed device include:

- Modify the design to allow the use of commercial 120 V lamps.
- Improve the interface for the user to determine the desired level of light. One possibility is to substitute the potentiometer for two buttons, one for increment and one for decrement.
- Add a display where the desired level of light is shown, preferably in some ligh unit, such as lumens, lux, or candelas.
- Add more light sensors. This would allow the device to diferentiate between local and general changes in the level of light, such as shadows or reflexes, and ignore the local ones.

– Add a motion sensor that would allow the device to know when the working area is in use and when it is not. This in turn would allow the device to shut down the light source and even set the microcontroller to sleep mode when the area is not being used, and to restart activity when there is motion detected in the area.
– Design and implement a better HMI, such as a remote control, that includes both the interface for determining the desired level of light and the display of its current value.

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