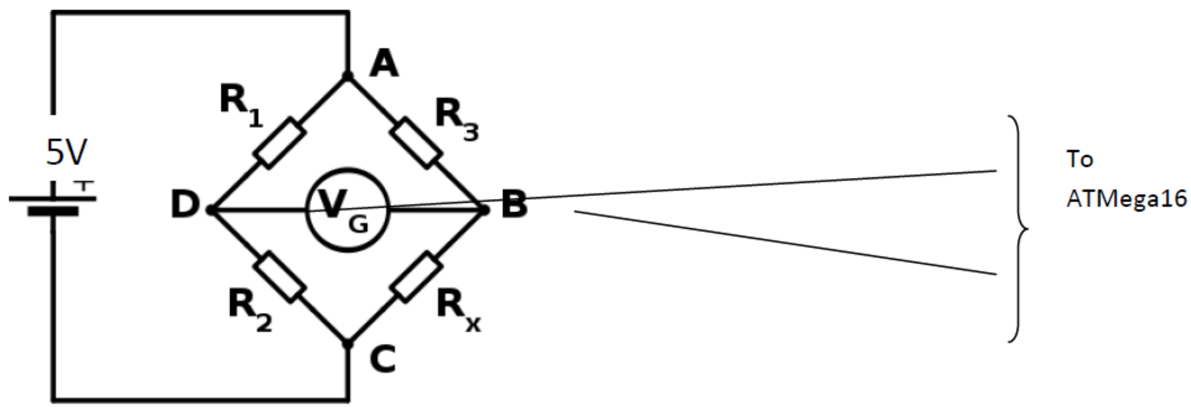
Embedded Hardware Design

Experiment4: Illumination Control using LDR

In this experiment, the brightness of a white LED will be controlled by detecting the illumination level by a light dependent resistance (LDR) placed right in front of the LED. As LDR gives a variation of resistance due to a change in illumination, the most convenient method for sensing the error between the desired level of illumination and the actual level is to setup a Wheatstone bridge as shown in the figure below. R1 and R3 are fixed resistances (2KΩ each) while the LDR is placed at Rx and a (10KΩ) potentiometer is placed at R2.

The unbalance voltage VG provides the error feedback to the micro-controller which is used to generate a Pulse Width Modulated (PWM) signal to control the current and hence the brightness of the white LED. The duty cycle of the PWM signal is adjusted according to the Proportional Control method, where the correction made is proportional to the error. The constant of proportionality plays a major role in the effectiveness of this control technique, as will be studied in this experiment.



Wheatstone bridge Arrangement

As the brightness of the LED would fluctuate at the frequency of the PWM signal, a capacitor is placed in parallel (as shown in the second figure) with the LED to filter out the high frequency and render the illumination constant.

Programming Requirements:

1. Write a routine to vary the brightness of white LED by varying the duty cycle of the PWM generated using 16-bit Timer/Counter 1 (PD5 pin) with the following parameters:
a). Waveform Generation Mode bits: In TCCR1A register, set the value of WGM11 and WGM10 as "10" and in TCCR1B register set the value of WGM 13 and WGM12 as "10" for Phase correct PWM with ICR1 as TOP.

b). Compare Output Mode: In TCCR1A register set the value of COM1A(1:0) as "10" so that it clears OC1A on compare match when up-counting and sets OC1A on compare match when down-counting.

c). Clock Select bits: In TCCR1B register, set the CS (12:10) bits as "010" for selecting a pre-scalar of 8.

d). Program TOP (ICR1 register) as 255 and vary the value in the OCR1A (mid) register for varying the duty cycle.
2. The Wheatstone bridge is initially balanced by observing the voltage VG on a multimeter and adjusting the potentiometer constituting the resistance R2 under ambient illumination.

3. Write a routine to initialize ADC hardware by programming the ADCSRA register for Single Conversion mode and ADC Pre-scalar division factor of 128. Perform A to D conversion of voltage values in Single conversion mode and display the value of the conversion on LCD. (Relevant registers: ADMUX, ADCSRA, ADC).

4. Now once the LED's light starts falling on the LDR, its resistance will change causing the bridge to get unbalanced. The voltages at terminals B and D are to be sent to the microcontroller which converts both the inputs to digital values using the ADCs, ADC0 and ADC1 (PA0 and PA1 pins respectively).

5. Calculate the difference between the two values of the ADC. For the system to be in a stable state this difference should not be greater than 10. If the difference exceeds 10, the duty cycle of the PWM is to be varied using the following formula.
$\Delta(OCR1A) = -(Kp * \text{difference})$
Where Kp is a proportional constant ranging between 0.01 to 0.1. Also keep a check so that the value of OCR1A is always between 25 and 230, representing 10% and 90% duty cycles respectively.
6. Display both ADC values, their difference and the value in OCR1A on the LCD screen. Refresh these values after a suitable number of iterations of the control loop, so that the display is reasonably free from flicker.

7. Study the effect of varying the value of Kp on the effectiveness of control and try to determine the optimum value of Kp which gives the fastest convergence, without overshoot and undershoot, to a new level of brightness if the potentiometer setting is changed.