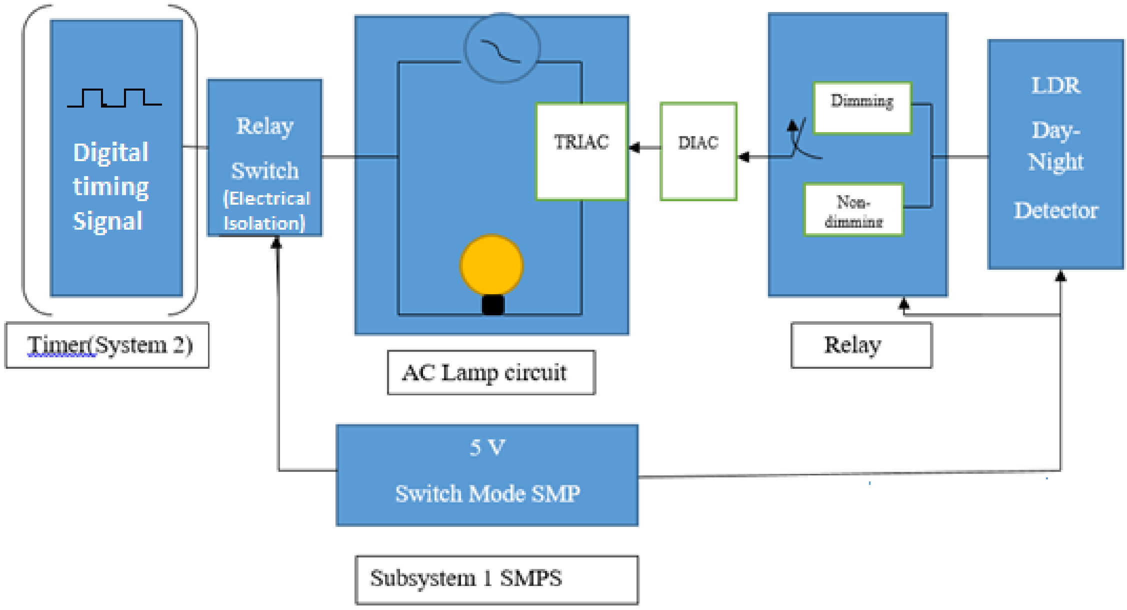
Sub-system 3: The traffic lights driver unit

The purpose of this circuit will be to receive the appropriate timing signals from Subsystem 2 to turn on the AC incandescent lighting. This system will also control the brightness of the three incandescent light bulbs depending on the ambient light conditions. If it is day, the lights should be at full brightness. If it is night, the brightness of the incandescent lamps should be dimmed to 60%. The low-power components of this system will draw power from Subsystem 1, which is the switched-mode power supply.

Hence, the circuit will meet these 3 primary specifications:

1. Interfacing the digital logic and timing from System 2 with the AC mains circuit to turn on the incandescent lights synchronously and appropriately.
2. Automatic day-night sensing using an optical sensor (like an LDR). This circuitry will draw power from Subsystem 1.
3. Adjusting the brightness to the load in accordance with the ambient brightness sensed using a triac for phase control dimming.

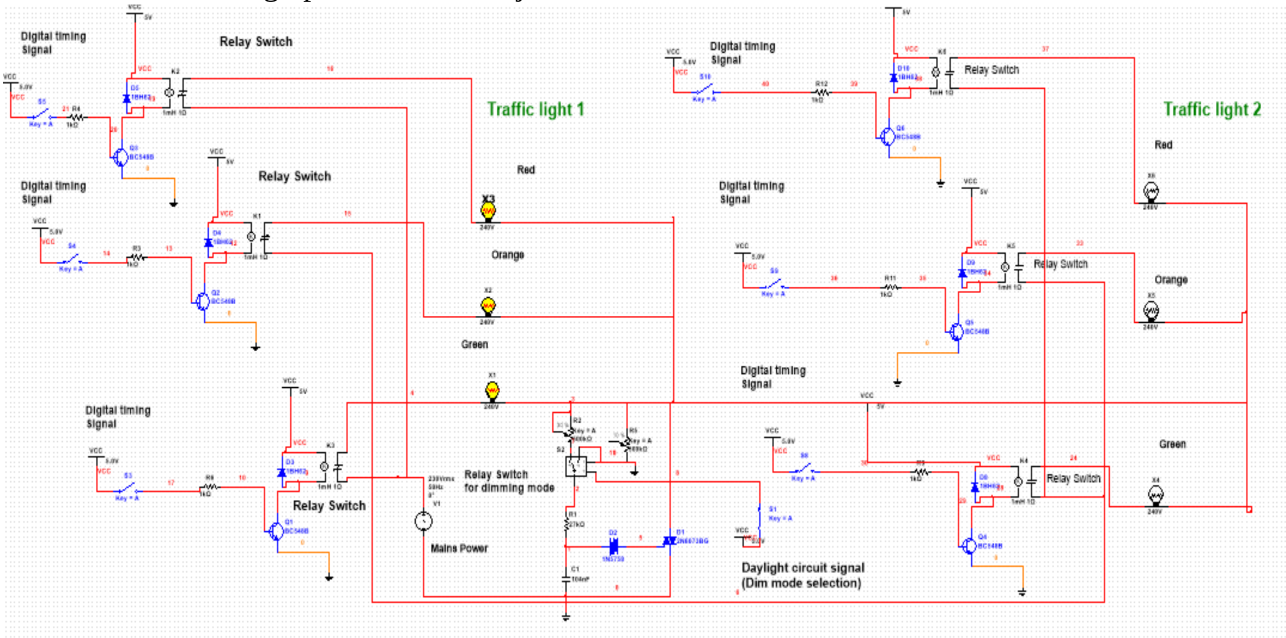
Conceptually, the subsystem can be envisaged in using the simplified block diagram shown in the following figure:



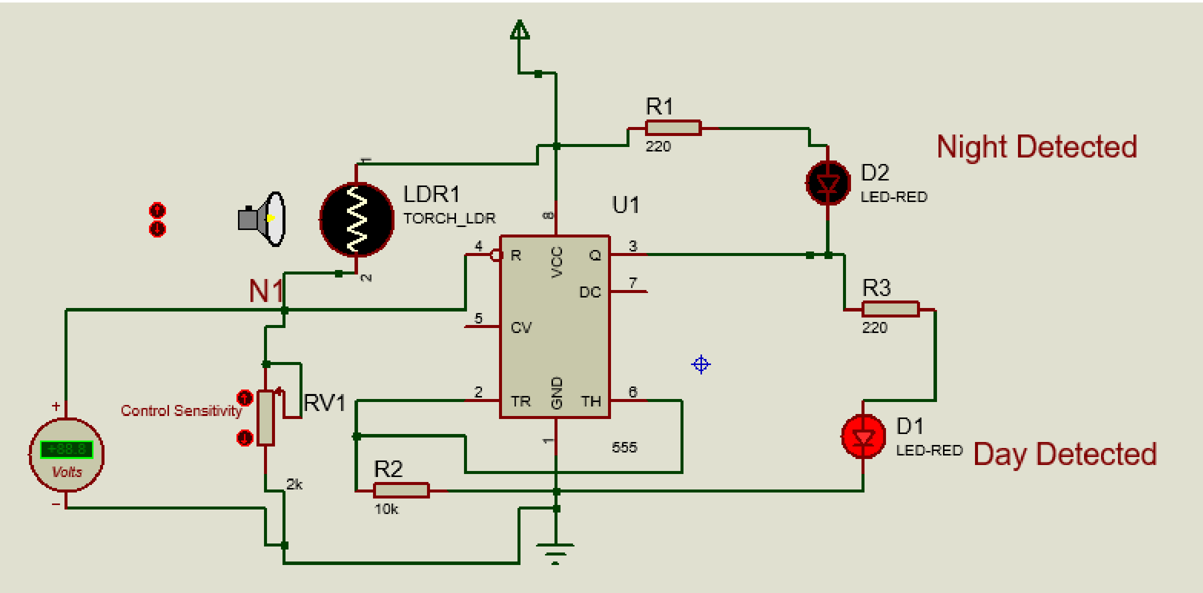
The preceding block diagram will be replicated for each light bulb, with the exception of sharing the same dimming circuitry. A parallel configuration of the incandescent bulbs will be implemented, and any dimming effects caused by this configuration due to current division will be negligible.

Circuit Diagram

The circuit diagram presented in the figure below offers a possible solution to the aforementioned design problems and objectives.



The digital timing signals will be obtained from Subsystem 2 and are represented as 5V signals in this circuit diagram. In the aforementioned figure, the daylight circuit has been simplified and will be substituted with the following circuitry for detecting day and night with hysteresis:

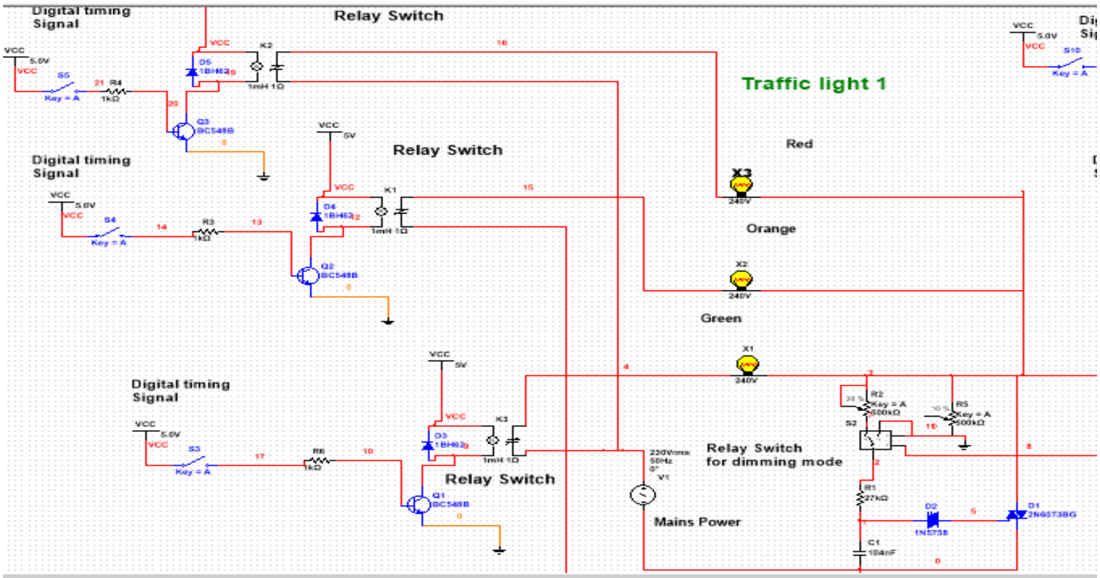


The digital timing signals will obtained from subsystem 2 and are roughly represented as 5 V signals in this circuit diagram.

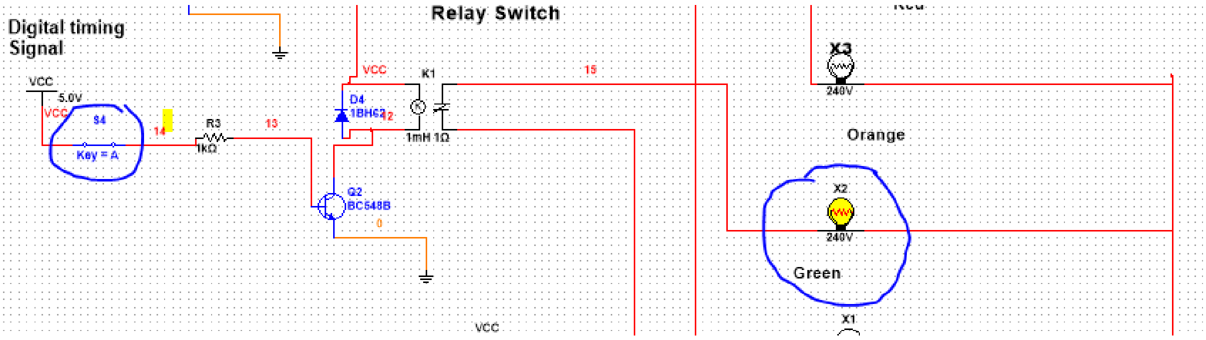
The mechanics and simulations are discussed in the subsequent sections.

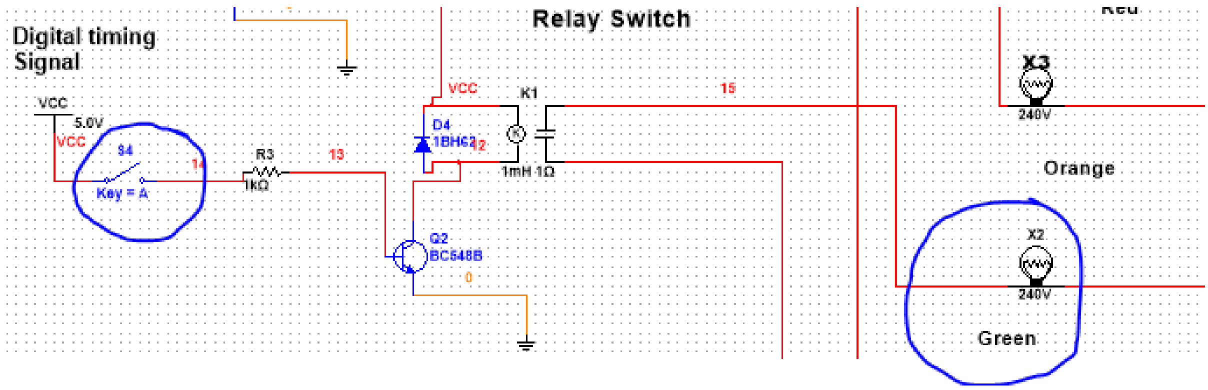
Interfacing with Sub-system 2: The digital logic control unit:

Digital timing signals, modelled as 5V VCC in combination with a switch, are received from Subsystem 2, as shown in the annotated figure below. These signals are then used to drive relay switches connected to their respective incandescent lamps. An alternative to these relay switches could be optocouplers to reduce component costs. However, the principle of separating high current from low current circuitry remains the same. In this case, relays are specifically used to ensure no simulation errors occur.



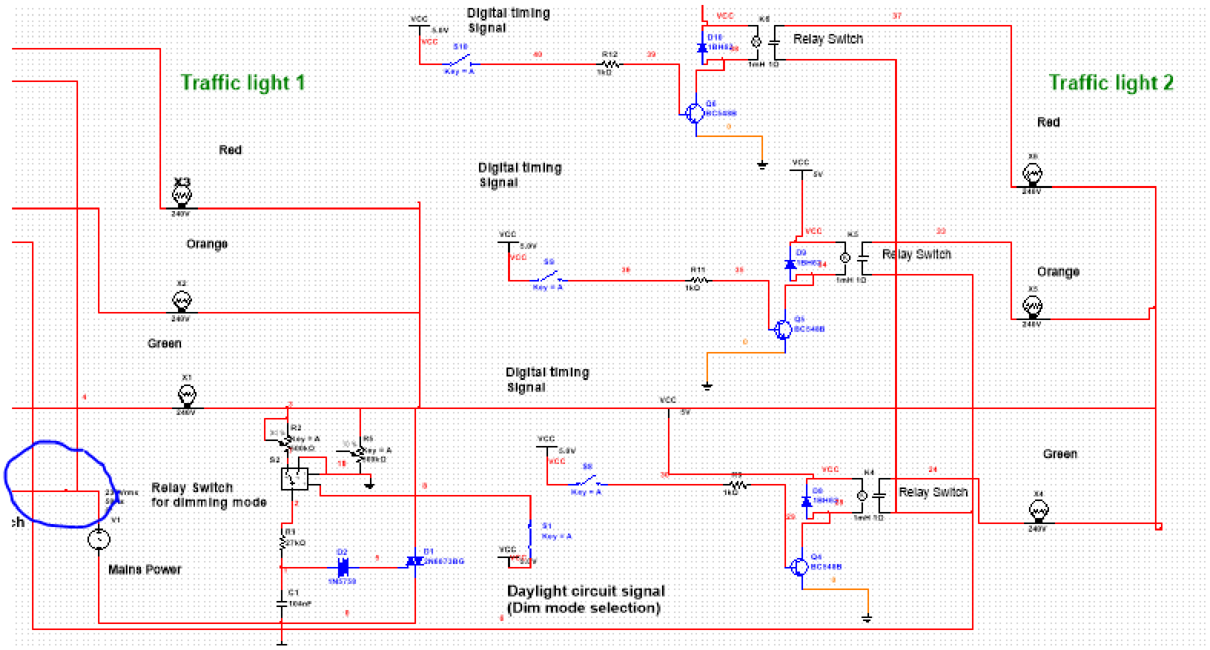
When a digital high signal is received from subsystem 2, the incandescent lamp is turned on and when a low signal is received, the incandescent lamp is switched off as shown in the following respective figures:





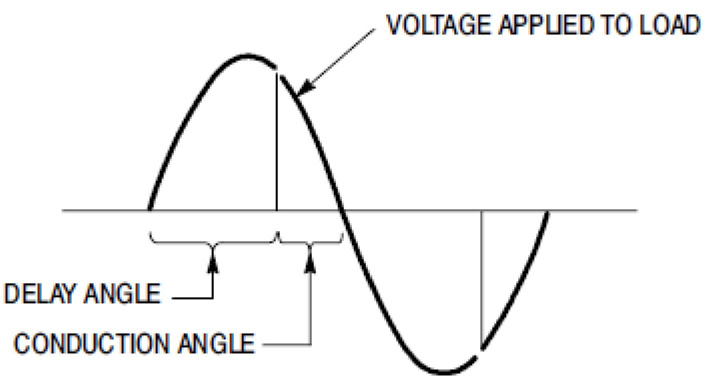
AC Circuitry:

The incandescent light bulbs are connected in parallel and share a common node, as circled in blue in the following diagram:

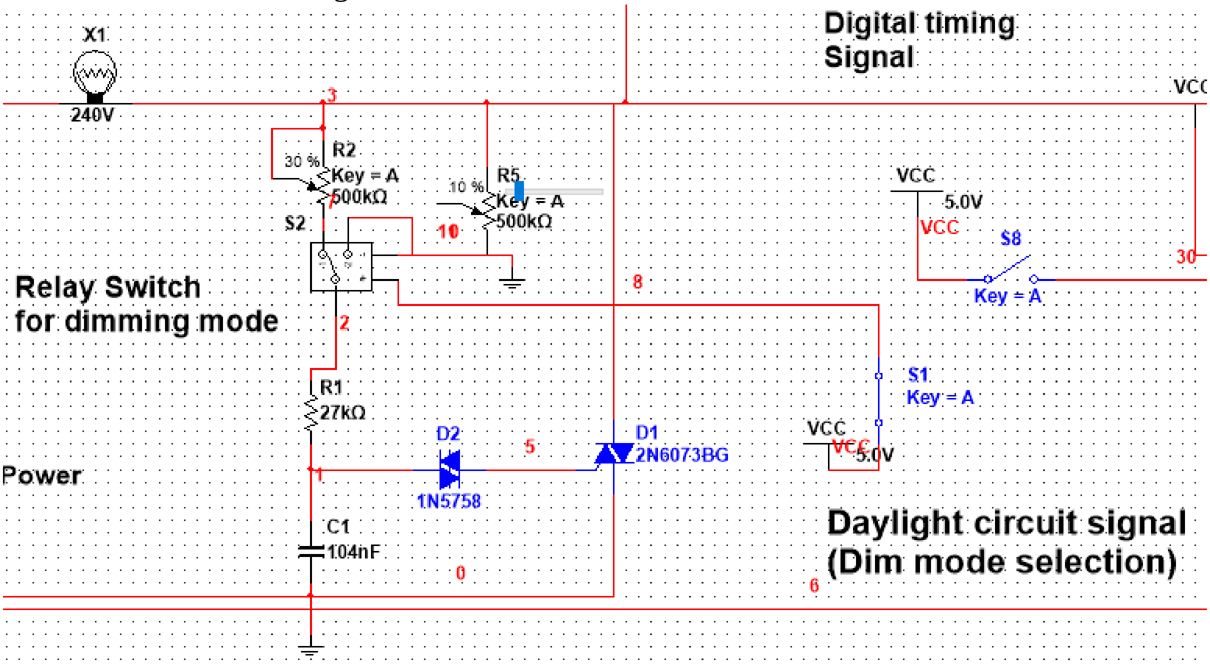


The Dimming Mechanism:

The AC circuit employs a diac-triac configuration to facilitate dimming of the incandescent light bulb. This operates on the principle of "phase-cut dimming." The triac turns off after each zero crossing and needs to be retriggered [7]. So by allowing for there to be a delay in the sine waveform, the net power to the load can be controlled.



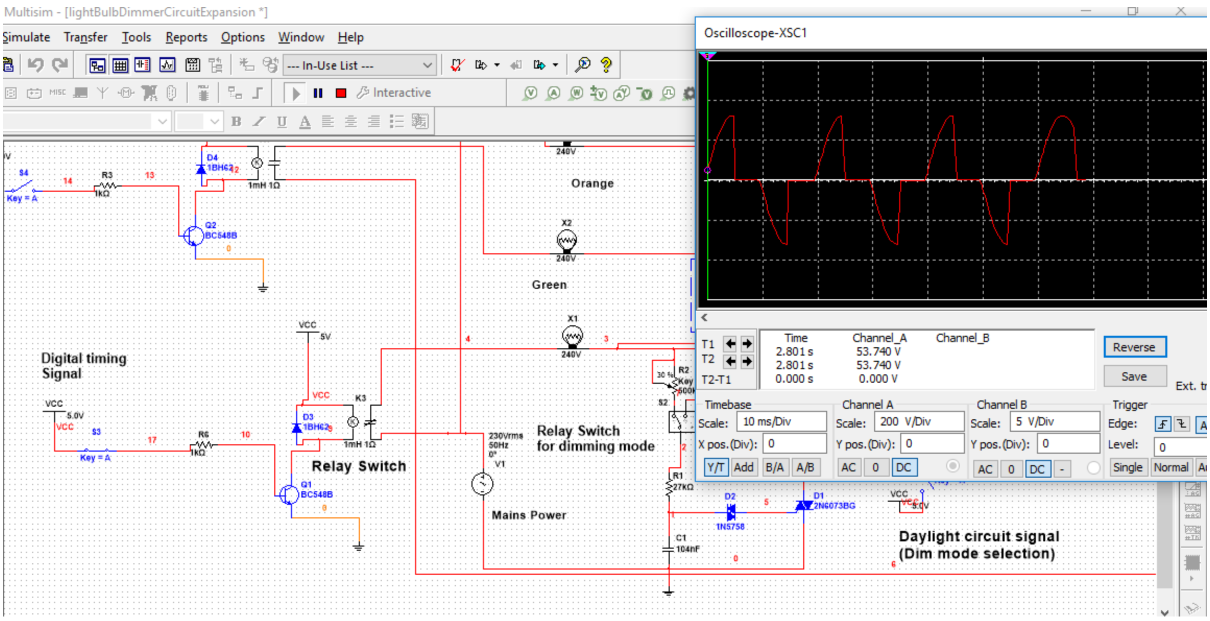
An RC network connected to the diac is utilized to control the delay time for re-triggering. This is illustrated in the figure below.



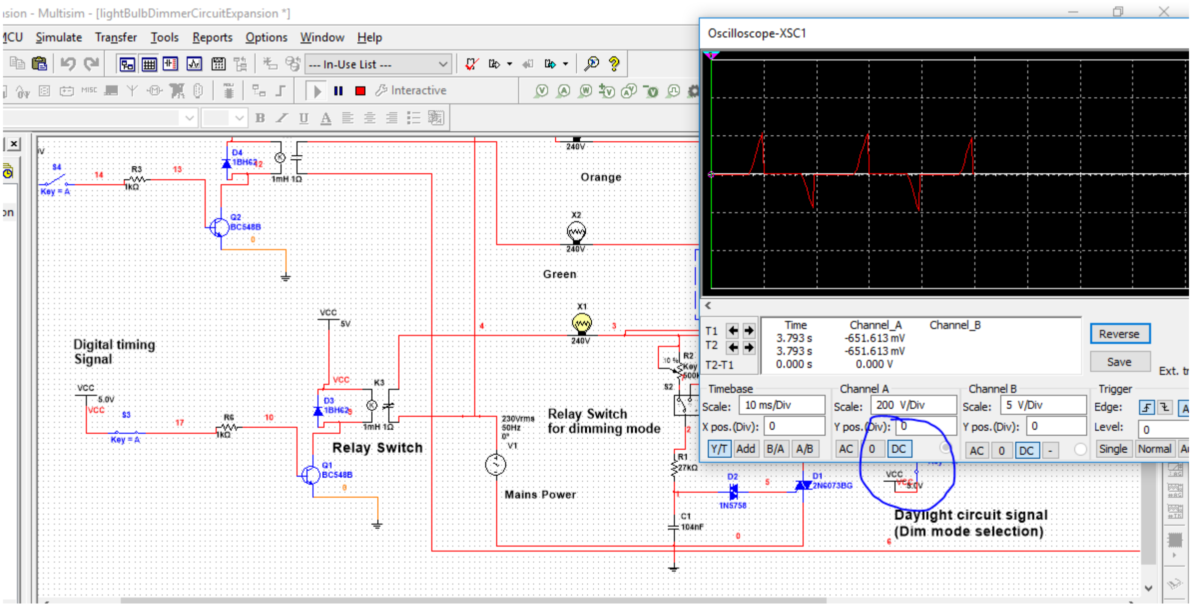
The net outcome is the modulation of the waveform, thereby reducing the power supplied to the lamp, resulting in dimming. A variable resistor (potentiometer) is employed to control the delay, allowing for a 60% dimming capability. Before the circuit can function automatically, the variable resistor is calibrated to allow for 60% dimming. This calibration will be achieved experimentally using either an oscilloscope or by using an instrument to measure brightness, such as a photometer. This simple dimming mechanism is chosen because of its simplicity and the ease at which it can be calibrated.

The figures below demonstrate the clipped AC waveform after potentiometer adjustment.

Before dimming, the following waveform and brightness is visibly shown. Note that the daylight detector switch is open:

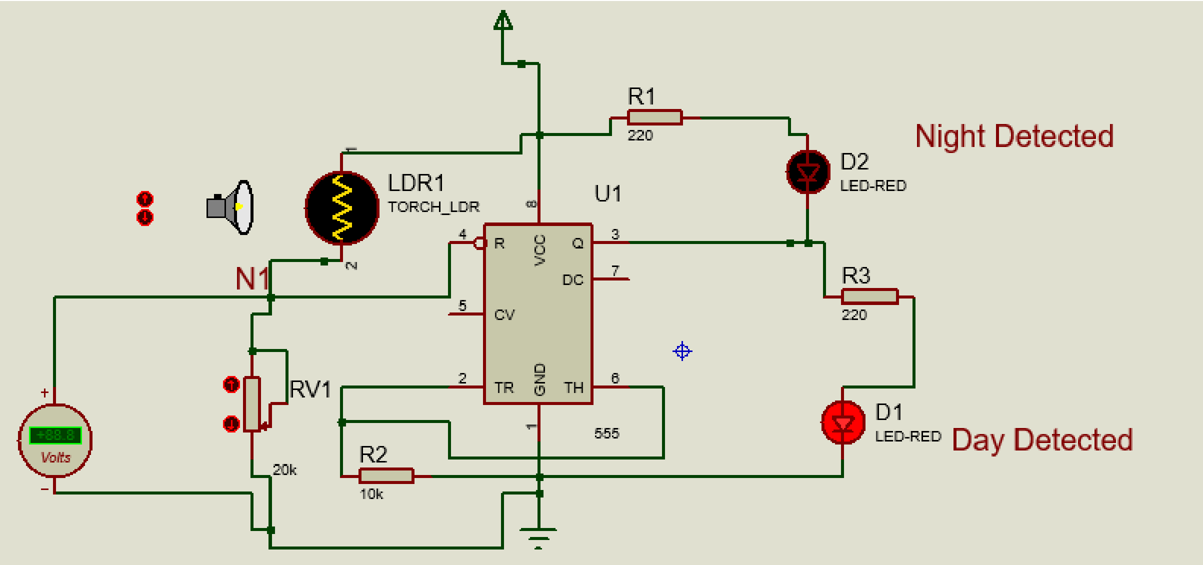


After dimming, by adjusting the potentiometer or initially calibrating it, the following waveform and brightness is visibly shown. Note that the daylight detector switch is closed:

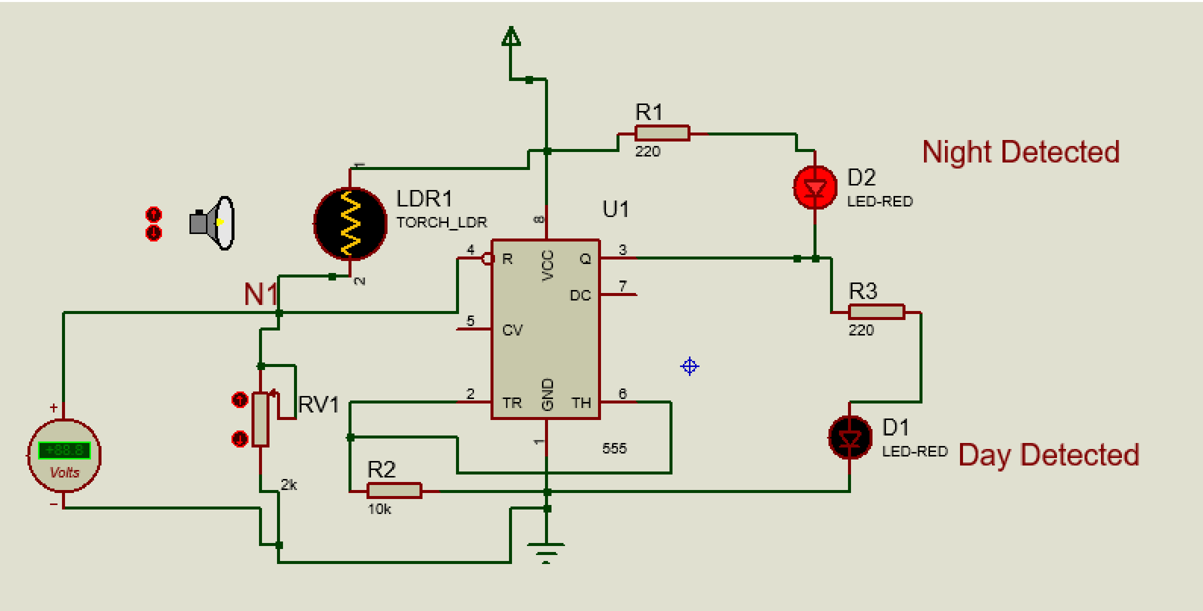


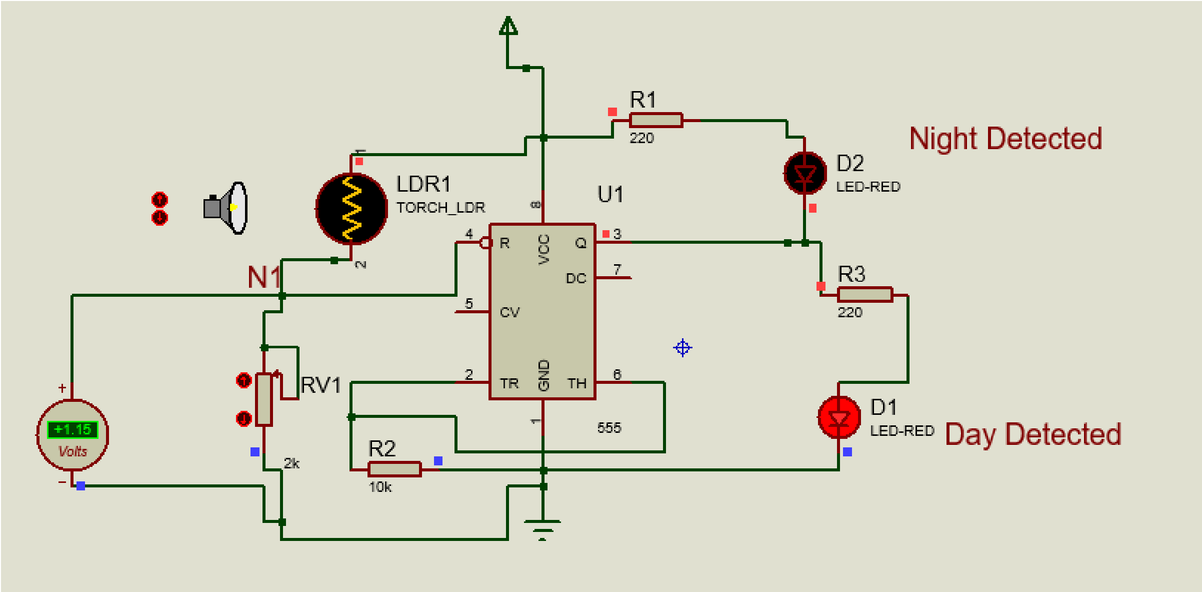
The Daylight Detector:

The daylight detector must have hysteresis to accomplish dimming. Several circuits could accomplish this end. For instance, a Schmitt trigger circuit could be used. In this solution, a simple 555 timer is used to accomplish this end. These ICs are very cheap, easy to procure, and easy to configure. The following circuit configuration is used as a daylight detector:



The mechanism of operation of this setup is that the voltage detected at the node labelled N1 will trigger the output of the 555 timer. This voltage is fed to the reset pin of the 555 timer, allowing the flip-flop in the timer to toggle the output. Quantitatively, if a voltage above 1.15 V is detected, the output of the 555 timer is set to high, and the LED labelled D1 is illuminated. If the voltage is below 1.15V, the output is set to low, and the LED labelled D2 indicates night. The potentiometer RV1, placed in a voltage division configuration, adjusts the sensitivity to ambient light intensity.[?] The following figures are simulations demonstrating this mechanism with a voltmeter measuring the voltage at the node N1.





The output detected can then be used to control a relay switch, which will dim the traffic lights, as discussed in the latter section.

Semiconductor, O.N., 2006. Thyristor theory and design considerations. *HBD855/D*, p.11.

https://elonics.org/light-sensor-and-darkness-detector-circuit-using-ldr-555ic/ , "Light Sensor and Darkness Detector Circuit Using LDR + 555 IC" , August 2021