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ACDB5002 - Electronics 1

Designing a Density Based Traffic
Light Controller using ultrasonic
and PIR Sensor

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Introduction

Microcontrollers and electronic sensors can be found in all areas of everyday life; from washing machines to AV equipment to smart home devices. This assignment will look at the use of microcontrollers and sensors in the context of a road junction with traffic lights and pedestrian crossings.

Traffic management systems, particularly on busy junctions, host a variety of sensors to detect oncoming vehicles and pedestrians in addition to coordinating the lights of the whole junction to ensure that traffic is allowed to flow in a safe and reliable manner. Unfortunately there can be no relying on the drivers themselves!

The road junction layout provided featured a cross roads junction with no additional turning lanes. Each road features a set of traffic lights for the oncoming traffic, with an ultrasonic sensor to detect oncoming vehicles. Each road also features a pedestrian crossing with a PIR presence detector, red/green LED and dual 7-segment display on either side.

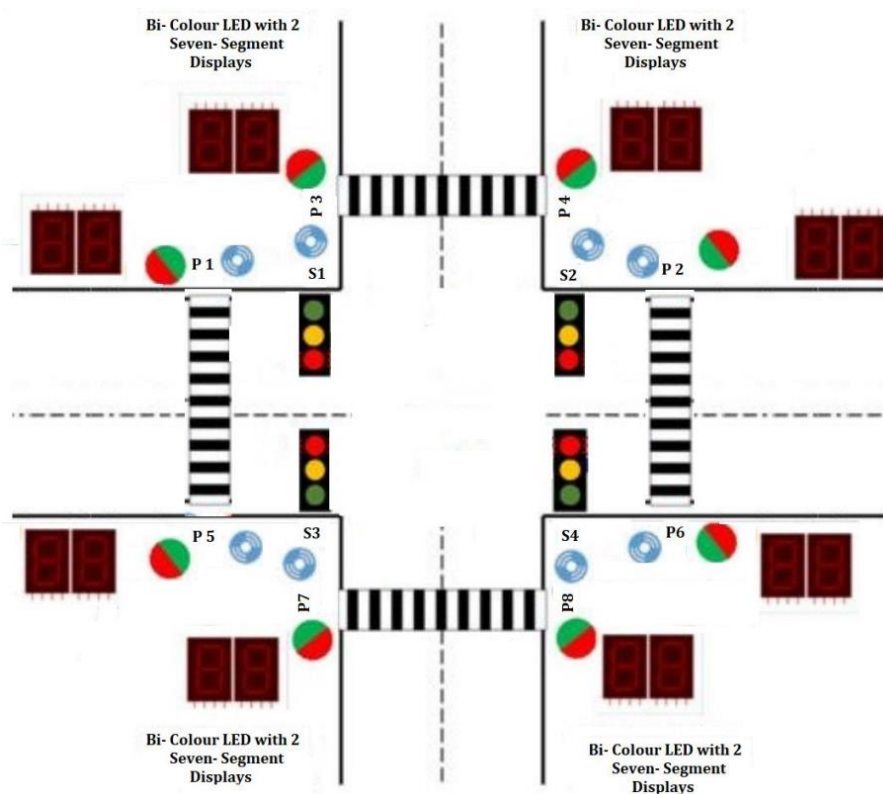


Figure 1 - Road junction diagram provided in the assignment briefing

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Background research

Road junctions with traffic lights typically use a variety of sensors to detect the presence of waiting vehicles[1]. These sensors include magnetic sensors embedded in the road surface, Inductive Loop Detectors, RADAR and ultrasonic.

Inductive Loop Detectors

Inductive loop detectors [2] are loops of copper wire embedded in the roads surface. When a vehicle with a sufficient ferrous mass passes over the top of the loop a magnetic and electric field is generated which can be detected by the roadside detection circuitry. Inductive loops are a great way to detect moving vehicles in a fixed location such as on the approach to a light controlled junction.

RADAR

RADAR is a system developed during World War 2 to detect enemy aircraft. The same principles can be applied to detecting road traffic in the modern day. RADAR works by transmitting a pulse of RF energy and measuring the time taken for a reflection to be received. The doppler-shift applied to the signal can support the RADAR in determining the direction and speed of a vehicle. Depending on the frequency of operation, a RADAR sensor can have a very fine or very rough granularity.

Magnetic Sensors

Magnetic sensors operate in a very similar manner to that of the Inductive Loop Detector however are typically much smaller but with a greater number of copper coils. Magnetic sensors can often be found in car parks where each parking space will feature a magnetic sensor to detect occupancy.

Ultrasonic

Ultrasonic sensors work in a similar way to that of RADAR except they work in the >20kHz audio band known as ultrasound. Due to the use of audio and being rather low power devices, ultrasonic sensors tend to have a relatively low range compared to that of RADAR. Less than 4m.

In the interest of developing a flexible and extendable system, I decided to investigate a distributed design based on a central controller and a microcontroller on each branch of the junction. This design methodology creates a modular system that can be easily updated with new turn lanes or different signals. With my modular approach, I will split the junction into a North, South, East and West Traffic light & pedestrian crossing, with each being monitored by a PIC16F877A. The 877A should offer plenty of IO.



There are two different protocols that are commonly used for communication between microcontrollers and peripherals, I2C and SPI.

I2C, or the Inter-Integrated Circuit Protocol, is a short distance communications protocol that allows microcontrollers transfer data to/from other microcontrollers and peripheral devices using just two connections [3]. The protocol consists of the SDA (Serial Data) and SCL (Serial Clock) connections and requires the Controller to transmit a 7 bit address to identity the peripheral that the data is intended for, then a 8 bit data packet.

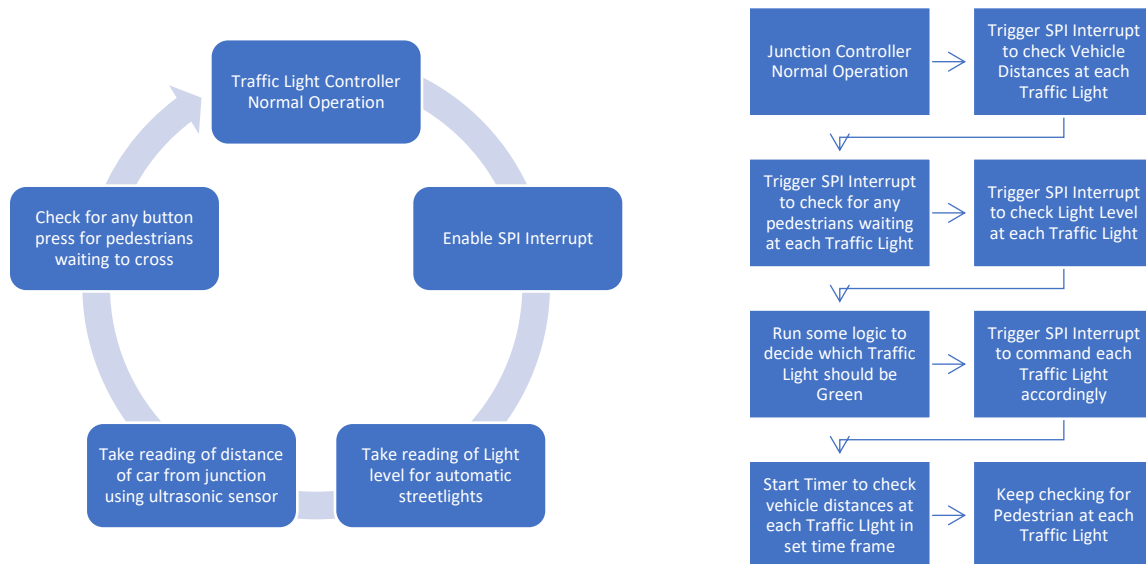
SPI, or Serial Peripheral Interface, is an older communications protocol for short distanced communications between microcontrollers and peripheral devices [4]. The SPI Protocol uses more pins than I2C by using separate PICO (Peripheral In Controller Out) and POCI (Peripheral Out Controller In) connections for the transfer of serial data in addition to the SCK (Serial Clock) and a CS (Chip Select) pin for each peripheral in the circuit.

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Ultrasonic Sensor

Ultrasonic sensors are devices that allow us to measure distances with a reasonably high level of accuracy (~3mm). The sensor works in the same way as RADAR in that when triggered it transmits pulses of 40kHz sound waves and measures the time for a reflection pulse to be received.

Concept of Operation



As shown in the above flowcharts the PIC16 managing the traffic lights and pedestrian crossing will be continuously cycling through reading the different sensors with an SPI Interrupt enabled.

Meanwhile the Junction Controller will be regularly triggering that SPI interrupt to check the status of each sensor and command the traffic lights and pedestrian crossing to change state.

Parts list and estimate of costing

Component	Quantity	Unit Cost	Total Cost
PIC16F877A	5	6.58	£32.90
Dual 7-Segment Display	8	1.51	£15.13 (order 10)
Ultrasonic Sensor	4	28.19	£112.76
SPDT Tactile buttons	8	3.00	£24.00
Traffic Lights	4	392.32	£1569.28
Ancillary passives			£100

Details of testing , simulated Outputs and results

To aid development of the road junction traffic control solution I first off built smaller test setups to investigate the Ultrasonic Sensor and SPI.

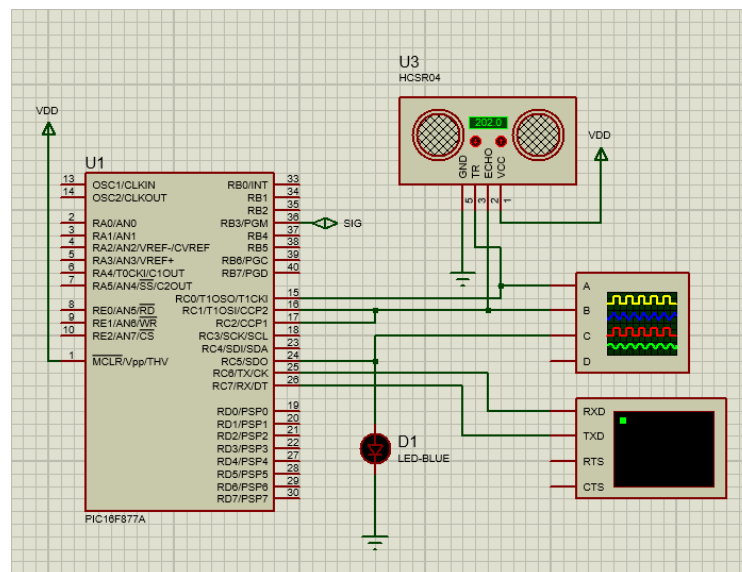


Figure 3 - Ultrasonic Sensor Investigation in Proteus

To aid my understanding of the HCSR04 ultrasonic sensor I initially made reference to the datasheet for the device [5]. Using the timing diagram found in the datasheet I was able to compile code that allowed my to read a value out of the sensor.

Additional Files such as Hex, Porteous Files, MP Lab or Mikro C Pro Files should to submitted through Moodle

References

- [1] S. Z. a. J. C.-C. Juan Guerrero-Ibáñez, "Sensor Technologies for Intelligent Transportation Systems," PubMed Central, 2018.
- [2] fortop, "Detection loops and loop detectors," fortop, [Online]. Available: <https://fortop.co.uk/solutions/products/loop-detectors-detection-loops/>. [Accessed 24 04 2023].
- [3] SFUPTOWNMAKER, "Sparkfun Tutorials - I2C," [Online]. Available: <https://learn.sparkfun.com/tutorials/i2c/all>. [Accessed 25 04 2023].
- [4] M. Grusin, "Sparkfun Tutorials - SPI," [Online]. Available: <https://learn.sparkfun.com/tutorials/serial-peripheral-interface-spi/all>. [Accessed 25 04 2023].