SMART Science and Mechatronics Aided Research for Teachers 2004

Integrating IR Sensors with a Microcontroller: Automated Regulation of Traffic Flow—A Mechatronics Demonstration Project [1]

[redacted]

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Division of Engineering Education & Centers

Abstract

An *Automated Highway System* (AHS) represents the evolution of the current interstate highway system making use of both intelligent vehicles and smart highways. The implementation of an AHS would require the inclusion of hardware both in the vehicles and in the roadway infrastructure. The latter would include roadside monitors that will: measure traffic flow, patterns of vehicular traffic volume, vehicle speed, vehicular routes, heavily trafficked intersections, and ways to prevent gridlock in vehicle-intense urban centers. In this mechatronics demonstration project, traffic flow is evaluated at one-way, perpendicular intersections by use of paired infrared (IR) sensors: an IR LED and a IR photodetector. The model roadways are designated as North-South (*NS*) and East-West (*EW*). The paired IR sensors work concomitantly and provide simultaneous input into a feedback loop with a Parallax Basic Stamp 2.5® microcontroller. The configuration of each sensor is that it represents 4-6 conventional-sized vehicles. If the IR sensor proximal to the light is triggered, then 4-6 vehicles are at the light and the green light is doubled (10 s). If the distal IR sensor is triggered as well, then 7-12 vehicles are present and the green light is tripled (15 s). The NS traffic light is only changed if vehicles are present in that direction. Similarly, the EW traffic light is only affected if vehicles are present in that direction. If no vehicles are present, then the default light cycle is in effect (i.e., there is a 5 s green light). Analysis of the results of this mechatronics project leads the investigators to predict that sensor-modification of the traffic-control cycle: (1) increases vehicle and pedestrian safety, (2) maintains reasonable rates of traffic flow at intersections, (3) decreases the likelihood of long wait-times at traffic lights, and (4) lessens the likelihood of gridlock at major inner-city intersections. A discussion of errors in measurement by IR sensors is provided for two-purposes: (1) showing the need to use IR devices in conjunction with others-as part of an array (e.g., other types of light, sound, etc.) to provide a more favorable and true representation of the environment being assessed; and (2) as segue to more comprehensive sensor analyses. Additionally, further studies are needed to: determine how the combination of IR sensors with other sensors can potentiate favorable effects. In addition, the intersection paradigm must be expanded to include: (1) two-way intersections, (3) entrance and exit ramps for interstates and highways, (3) interstates and highways themselves, and (4) urban, suburban rural roads.

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Curriculum Standards Correlation

This project deals with the topics of: electric current, electric circuits, electromagnetic induction, electromagnetic applications, torque on a current carrying loop, electron beams, and c. induced voltage that are included in the New *York State Science Standards #4 of the Physical Setting*.

This project further supports the following *New York State Standards* as they relate to this project

In terms of content and processing skills:

Standard 1: Analysis, Inquiry, and Design—will use

- mathematical analysis
- scientific inquiry
- engineering design

as appropriate, to pose questions, seek answers, and develop solutions.

Standard 2: Information Systems—will

- access
- generate
- process
- transfer

information using appropriate technologies.

Standard 4: Science will

- understand and apply scientific concepts, principles, and theories pertaining to the physical setting recognize the historical development of ideas in science.

Standard 5: Technology will

- apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs.

Standard 6: Interconnectedness: Common Themes will

- understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Standard 7: Interdisciplinary Problem Solving will

- apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Introduction

Despite increasing traffic congestion, Americans still depend on the automobile for mobility, and there's no trend towards change. Cars continues to dominate urban travel among every segment of the population. In 2002, more than 9,400 people were killed and 1.4 million injured in crashes at intersections (Funderburg, 2004). Drivers need help in driving safely and avoiding traffic accidents at any point on the roadway: entrances, highways , exits and intersections.

Transportation has enabled the creation of the modern city, but the public's increasing need to travel and the difficulty of providing additional capacity to accommodate this travel has increased congestion and reduced mobility in many cities. Current technology for intelligent transportation systems (ITS) can provide the potential to improve the operations and efficiency of travel by providing information that can help drivers make better use of existing facilities.

Population and number of households have continued to increase in most areas. There is a perceived need to accommodate this growth by rebuilding the roadway infrastructure (i.e., roadways themselves). The shortcomings in the roadways coupled with the longer travel distances to existing work places and other services, cause major increases in automobile travel. Transportation demand has typically greatly exceeded the population growth. Transportation improvements will benefit the roadways if the improvements facilitate the movement toward an effective transportation system.

Technology offers the most potential to address the problems in cities and has been termed **automated vehicle guidance** (AVG). AVG is a technology that allows individual vehicles to move without physical control by a driver. AVG technology has taken many forms, the most common elements include in-vehicle and roadway infrastructure components. The in-vehicle components might include:

(1) a controller/processor

(2) sensors to detect the presence of other vehicles, roadway location, and vehicle roadway position

(3) an interface with the in-vehicle communication to provide: current speed, acceleration rate, direction of movement, and steering status, accelerator, and braking controls

(4) actuators by which the system can control the throttle, brakes, and steering;

(5) a radio transceiver to communicate to ←→ from other vehicles and the infrastructure

(6) human interface displays and controls.

The roadway infrastructure components might include:

(1) the roadway itself (may or may not be dedicated to AVG vehicle use)

(2) roadway markings used to delineate the roadway to the vehicle

(3) traffic control devices such as signals that can regulate the flow of automated and manually driven vehicles at points of intersection

(4) access control facilities to restrict use of the facility and protect the automated vehicles from external threats such as animals or errant vehicles

(5) a traffic management system that can direct the flow and protect the safety of all vehicles

(6) roadside transceivers to communicate with the automated vehicles.

A technological synergy between an intelligent transportation systems and automated vehicle guidance forms the nucleus of a proposed automated highway system (*AHS*). The implementation of AHS is intended to ameliorate:

(1) traffic flow

(2) patterns of vehicular traffic volume

(3) excessive vehicle speed

(4) chaotic vehicular situations

(5) heavily trafficked intersections

(6) gridlock in vehicle-intense urban centers

Ultimately, the goals for the technological synergy are:

(1) increased vehicle and pedestrian safety

(2) maintenance of reasonable rates of traffic flow at intersections

(3) decreased the likelihood of long wait-times at traffic lights

(4) decreased probability of gridlock at major inner-city intersections

Background

Remote sensing is defined as, " … the science of deriving information about an object from measurements made at a distance from the object without making actual contact ." (Campbell, 1996). While remote sensing encompasses numerous detection technologies, three platforms are applicable to transportation:

(1) space-based

(2) aerial

(3) in-situ

For the purposes of this investigation, only in-situ sensing in the form of infrared detection is used because of the constraint of time and the desire to develop a simple sensor paradigm. Infrared light or IR has lower frequency than red light. It is not part of the visible spectrum. It can be used in a number of applications, including:

(1) night-vision goggles

(2) temperature sensors

(3) object detection

(4) object counts

(5) distance determination

When used in a microcontroller-based circuit, IR LED's can be integrated with a timing algorithm, so that combination of an IR transmitter and an IR detector can monitor the presence of vehicles stopped during the red-traffic light at an intersection.

At intersections that have experience heavy traffic patterns, traffic lights are put in place to regulate the flow of vehicles to: insure safety, reduce traffic, prevent accidents involving pedestrians and/or vehicles, and prevent grid-lock. The light operate through a standardized cycle that involves:

Green—Yellow → **traffic flow enabled**

Red → **traffic flow prevented**

The duration of the green-yellow and the red phases of the traffic signal cycle is a function of the magnitude of the vehicle retinue *or* vehicle line *at the intersection. If there are no cars in either direction, then there is a default time setting. As the line of cars increases, the green-yellow phase increases.*

This is a simple model that can has room for expansion depending on the volume of traffic. Other features can also be built in if needed including the capability of sensing vehicles that , “run red lights”, prevention of vehicle crashes, pedestrian accidents, etc..

Components

Diode [http://electronics.howstuffworks.com/led1.htm]

A diode is a simple semiconductor that allows current to flow in one direction only. Current is not allowed to flow in the opposite direction. Diodes consist of two types of material:

- N-type material
- P-type material.

N-type material has extra electrons and P-type material has extra electrons. This project uses diodes to protect transistors. Without the diode, the kickback voltage that is created when the field through the coil collapses could overload and thereby "burn out" the transistor.

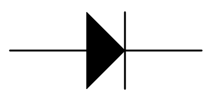


Figure 1: Schematic of diode

Figure 2: Diode

Infrared Emitter Diode [http://www.howstuffworks.com/led.htm]

An Infrared Emitter Diode is a Light Emitting Diode (LED) that produces a light in the infrared range. Although this light cannot be seen by humans, it can be detected by infrared sensors. A light emitting diode is a diode that produces a light of a certain frequency when current is passed through it. Like the diode, it will only conduct electricity in one direction. The negative side of an LED can be identified by its shorter leg and flat spot.

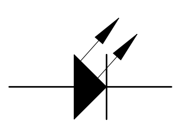


Figure 3: Schematic of LED

Figure 4: LED

Transistor [http://www.angelfire.com/ny3/diGi8tech/TGlossary.html]

A transistor is a semiconductor switch. Through one circuit, another circuit can be controlled. Transistors have three legs: the base, the collector and the emitter. When the base is activated, current is allowed to flow from the collector to the emitter. There are two basic types of transistors: NPN and PNP. The NPN requires a positive voltage at the base to cause current flow from the collector to the emitter. The PNP requires a negative voltage at the base to cause current flow.

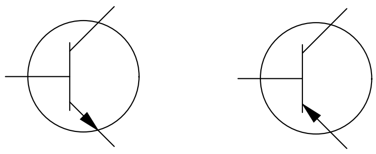


Figure 5: Schematic of NPN and PNP transistors

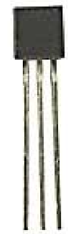


Figure 6: Transistor

IR Phototransistor [http://www.angelfire.com/ny3/diGi8tech/TGlossary.html]

Like the transistor, the phototransistor is an electronic switch. Unlike the transistor though, the phototransistor has only two legs. The phototransistor conducts current from the collector to the emitter when the base is exposed to infrared light. When the base is not exposed to infrared light, current is not allowed to flow from the collector to the emitter. In this project, the IR phototransistor is used with the IR emitting diode. Together, they detect the presence of a vehicle.

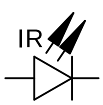


Figure 7: Schematic of IR Phototransistor

Figure 8: IR Phototransistor

Resistor [http://www.wordiq.com/definition/Resistor]

A resistor is an electrical component that is designed to have an internal opposition to current flow. It is designed to be stable and consistent under a wide array of conditions. Resistors are used in this project to divide voltage and limit current. Using Ohm's Law, an appropriate resistance can be determined to produce a desired current flow.

Figure 9: Schematic of a resistor

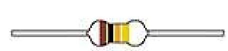


Figure 10: Resistor

Lamp [http://science.howstuffworks.com/light-bulb2.htm]

A lamp is a generic turn for a light bulb with a housing. The lamp includes a bulb, base and wires. A light bulb is made of a filament, two wires, a base and a glass housing. Current flows from one of the wires connected to the base, through the filament inside the glass housing and back through the other wire. Light bulbs convert electrical energy into heat energy and subsequently, light.

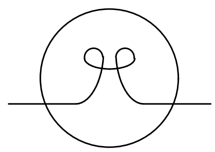


Figure 11: Schematic of a lamp

Figure 12: Lamp

Relay [http://electronics.howstuffworks.com/relay.htm]

A relay is an electromechanical switch. It is electrically operated. When current is sent through a coil, a magnetic field is created. That magnetic field turns the relays steel core into a magnet that closes a set of contacts. Relays have four pins. Two are for the coil that operates the electric switch and the other two are the contacts of the switch. This project needs relays because the lamps used exceed the current limits of the controlling transistors. To turn a lamp on, a signal is sent to a transistor that closes the circuit containing the relay's coil, that closes the contacts of the relay and hereby illuminating the lamp.

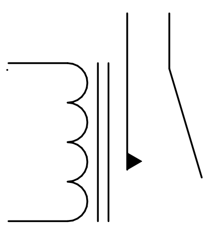


Figure 13: Schematic of a relay with contacts

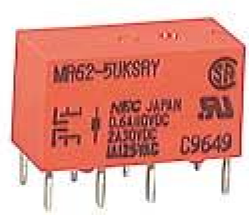


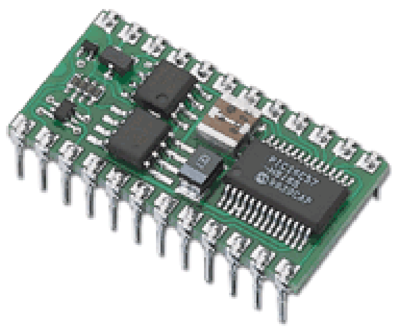
Figure 14: Relay

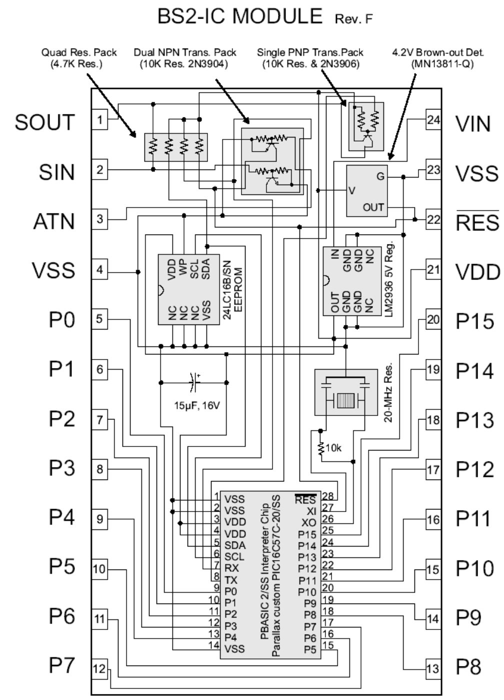
Basic Stamp Module®: Microcontroller3

The BS2-IC is the single most popular BASIC Stamp module. Widely used in educational, hobby, and industrial applications. This module normally has no shortage of program space or I/O pins. Serial PC interface provides enhanced debug features.

The BS2-IC is recommended for first-time BASIC Stamp module users because of the many resources, documentation, source code, and customer projects that are available for the BS2-IC. Our educational curriculum is also based on this module, making it a great place to start. Once you have become familiar with programming in

PBASIC and have designed your own projects, you may want to explore our selection of Stamps with increased power, speed, or memory.





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Board of Education®

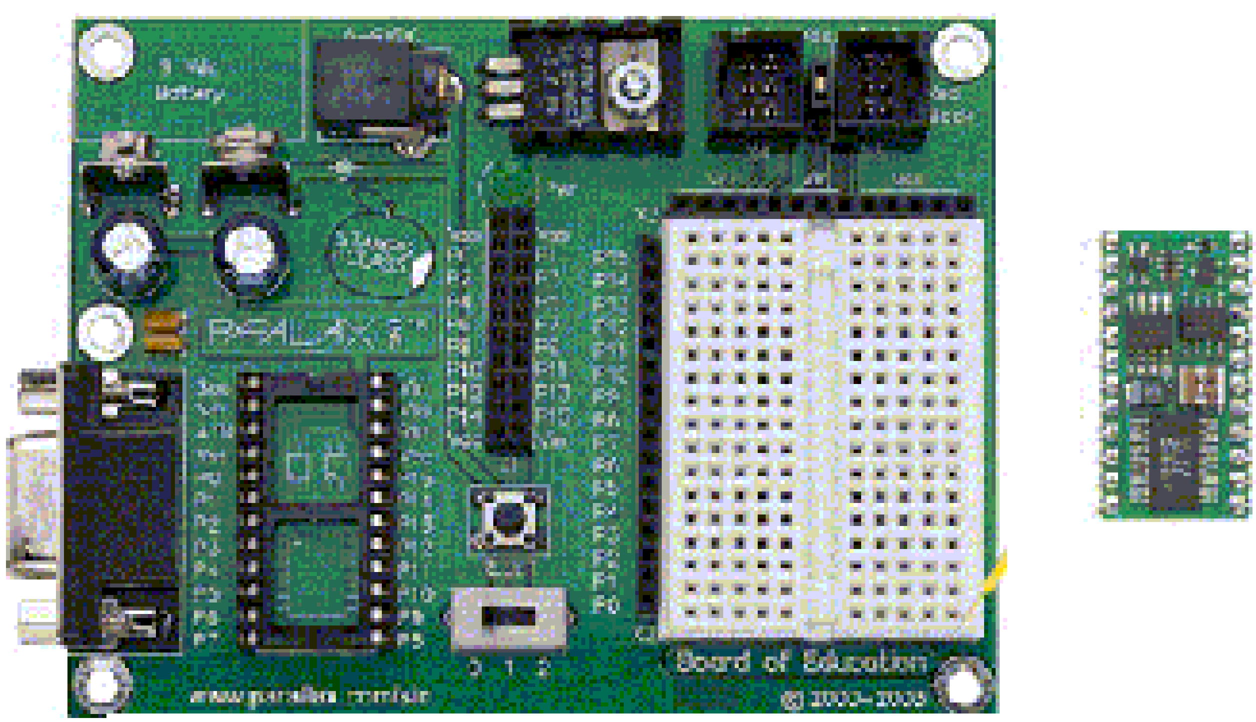
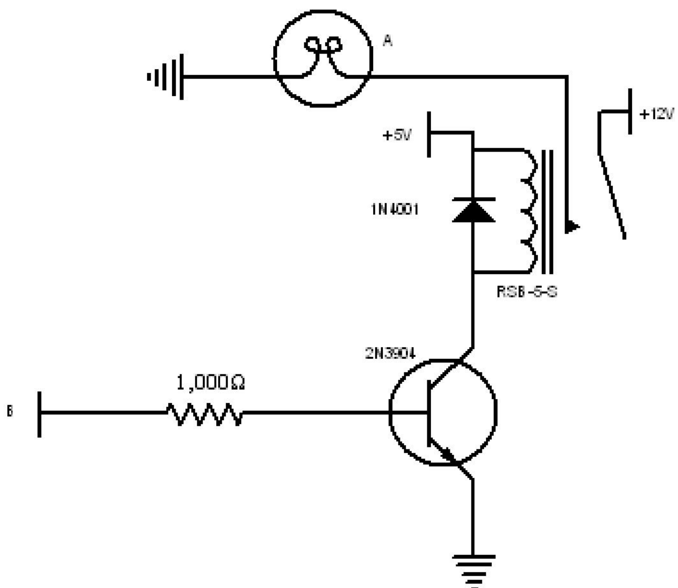


Figure 16 Parallax Board of Education® with Basic Stamp®

The Board of Education®, Revision C programming board has two major changes from the Revision B. The jumper near the servo connectors will select either Vdd (5 V) or Vin (unregulated input voltage) to power the servos. The three-position power switch is either off (0), power to everything but servo connectors (1), or power to everything (2).

The Board of Education carrier board is available here as a separate programming board or you may purchase the "BOE" Full Kit. The majority of the Stamps in Class curriculum requires a BASIC Stamp 2 module with a Board of Education carrier board. The BOE was designed in coordination with our educational customers to teach microcontroller programming and interfacing. Even if you aren't using our curricula, it's still an ideal project board for instructor-authored BASIC Stamp lessons.

A. Figure 17—Schematic Circuit Diagram of the ***Infrared Signaling System*** **(LED's)**



BILL OF MATERIALS

QTY.	Ref No.	NAME
6	9	Resistor 1K Ohm
6	6	Relay
6	8	Transistor
6	7	Diode
2	10	Lamp, Red
2	11	Lamp, Yellow
2	12	Lamp, Green

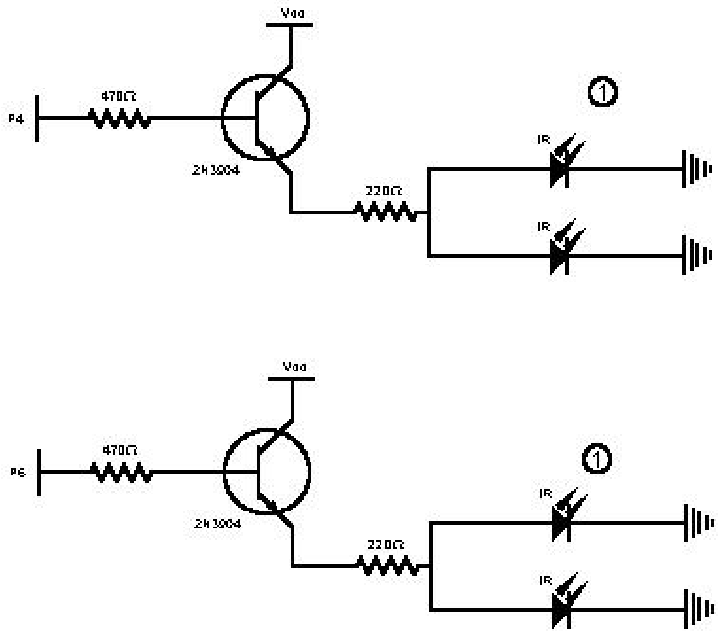
Pin No.	Lamp Color	Street
7	Red	NS
8	Yellow	NS
9	Green	NS
10	Red	EW
11	Yellow	EW
12	Green	EW

NOTES:
1. The portion of the circuit represented above occurs six (6) times in the complete circuit.
2. All instances are identical, with the exception of items A and B.
3. "A" represents the bulb color and location. "B" represents the Basic Stamp pin.
3. See the chart to the right for lamp (A) and pin (B) identification.

Infrared Traffic Signal

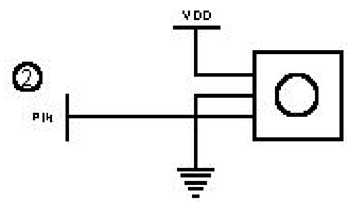
DRAWN Koumoullos, M	SIGNALING SYSTEM
DRAWN Winston, R	
DATE 07-22-2004	SIZE A — DWG NUMBER 0000-0002
SCALE NONE	REV - — SHEET 1 OF 1

B. Figure 18—Schematic Circuit Diagram of the ***Infrared Detection System***



BILL OF MATERIALS

QTY.	Ref No.	NAME
1	17	Resistor 470 Ohm
1	20	Resistor 220 Ohm
4	4	IR Emitter Diode
4	5	IR Photo-sensor
2	8	Transistor



IR Sensor Pins 3

Pin No.	Road	Position
0	NS	Near
1	NS	Far
2	EW	Near
3	EW	Far

NOTES:
1. The IR LEDs flash at 38.5 kHz with a 50% duty cycle.
2. See the chart to the right for IR sensor pin identification.
3. Near/Far refers to the distance from the intersection.

Infrared Traffic Signals

DRAWN Koumoullos, M	DETECTION SYSTEM Infrared LEDS and Infrared Sensors
DRAWN Winston, R	
Date 8-05-2004	SIZE A / DWG NUMBER 0000-0001

Results

This engineering paradigm interfaces a pair infrared sensors: an IR LED and an IR photodetector in an electrical feedback loop with a series of light bulbs (green, yellow, and red).   The three lights represent an intersection traffic control signals.

The flow of information in the model can be visualized using the following scheme:

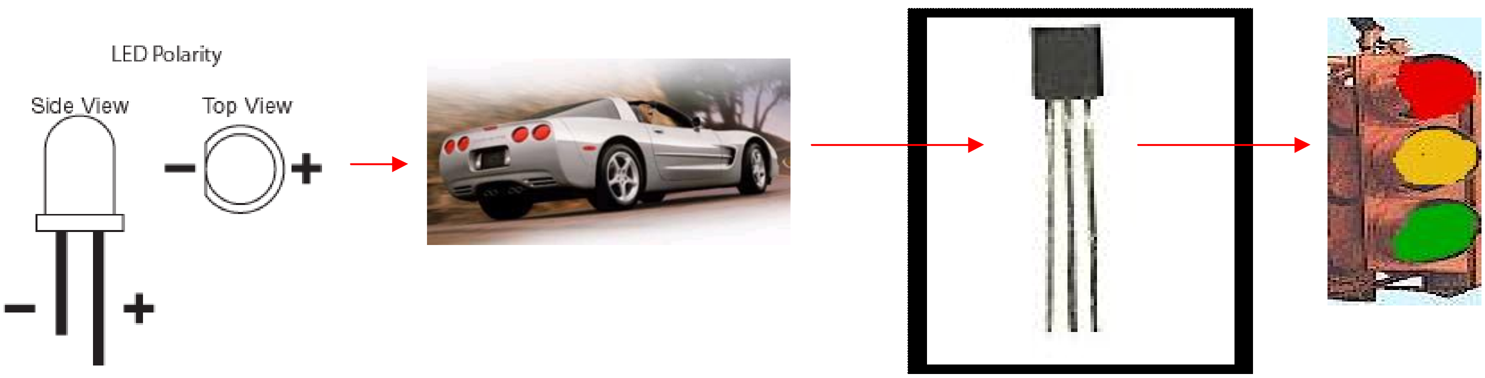


Figure 19—Disturbing the flow of information after sensing a motor vehicle.

The configuration in the above diagram represents the flow of information in the system if the IR sensors are triggered resulting in a change in the default setting of the model traffic light. The default setting is such that the green light is 5 s in duration.   When the sensors are triggered, the default cycle is changed in the direction of the traffic flow: either North-South (NS) or East-West (EW). The system as whole represents a sensor-sensitive light switching system.   The signals are regulating the flow of traffic at a virtual perpendicular urban or suburban intersection.

The duration of the green light is a function of the length of the traffic line stopped at the intersection in a NS, EW, or NS and EW direction. For the sake of brevity and keeping with the whole concept of modeling, the default green light is 5.0 s in duration. Each pair of IR sensors-if triggered-represent 4-6 conventional sized vehicles. When a pair of sensors in a particular direction is triggered, the information is relayed by use of a feedback loop and the duration of the green light is increased to 10 s.   The change in the traffic signal cycle depends on the number of sesnors triggered and in what direction the traffic is going. When two sensors are triggered in a particular direction, the time of the green light is increased to 15 s

The table that follows, summarizes the changes in light signaling that are result of feedback between the IR LED's—sensors and the vehicles in the model.

Table 1—The Traffic Signal Cycle with and without sensor triggering

Color of Traffic Light Signal	Duration of the Signal Light (in s) as a function of the number of IR sensors triggered					
	0 (<4 vehicles)		1 (4-6 vehicles)		2 (7-12 vehicles)	
	Compass (Directionality)					
	N-S	E-W	N-S	E-W	N-S	E-W
Green	5	5	10	10	15	15
Yellow	2	2	2	2	2	2
Red	9	9	14	14	19	19

Notes:
N-S = North-South
E-W = East-West

The series of JPEG's that follow (figures 20—23) included on the subsequent pages reflect the observed changes in the default traffic patterns which appropriately mitigate changes in the sequences and timing of the intersection traffic lights. The changes effected are function of the number of IR sensors triggered (Table 1).

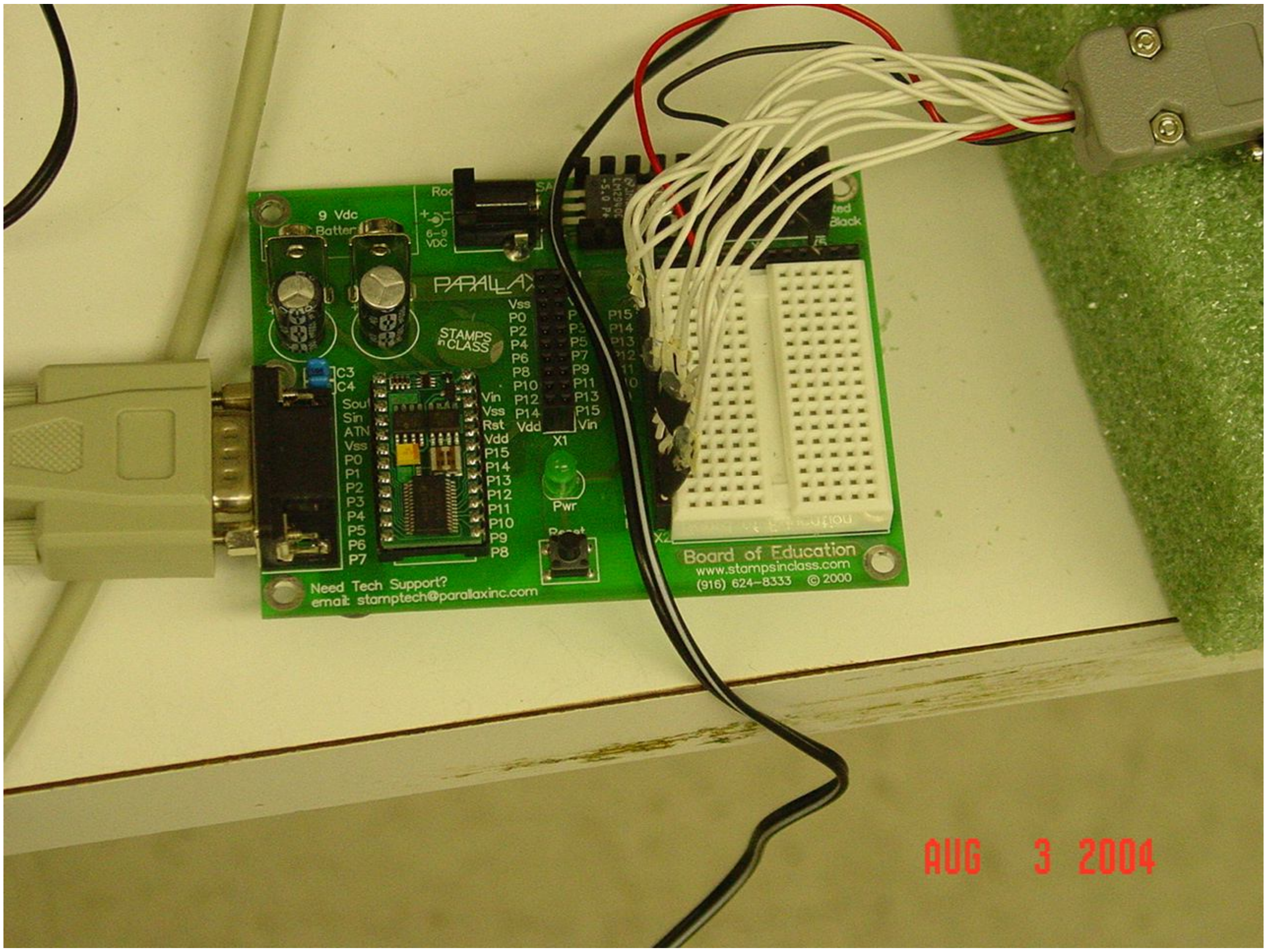


Figure 20—The BOE acting as an interface.

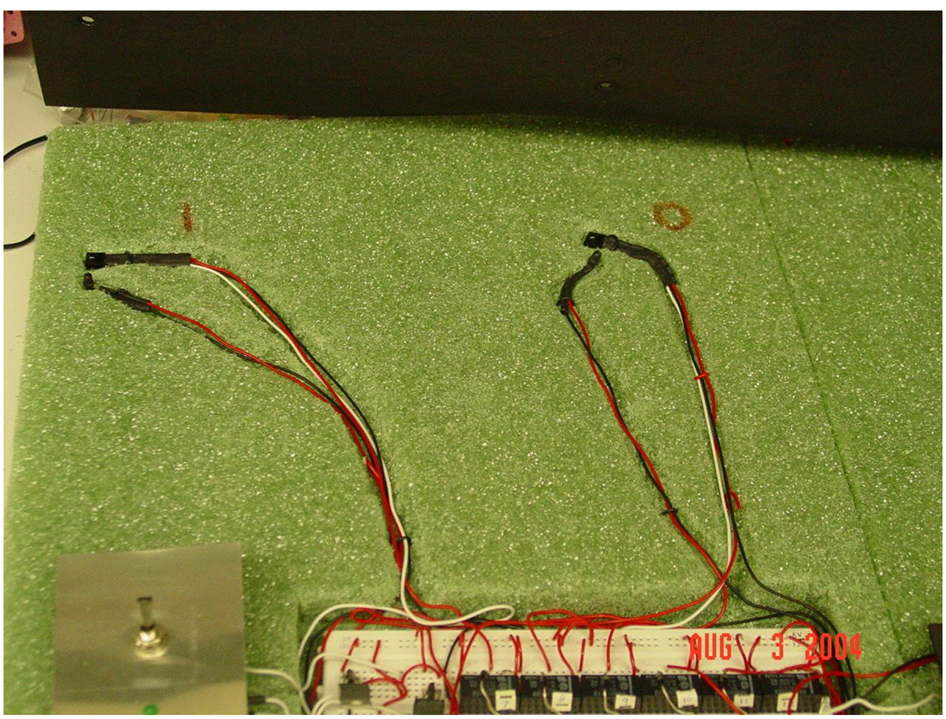


Figure 21—Individualizing and hiding wires.

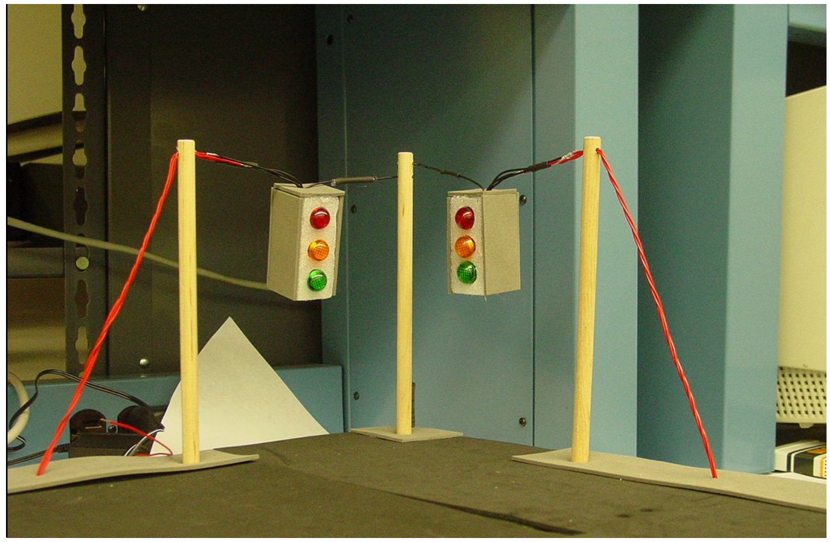
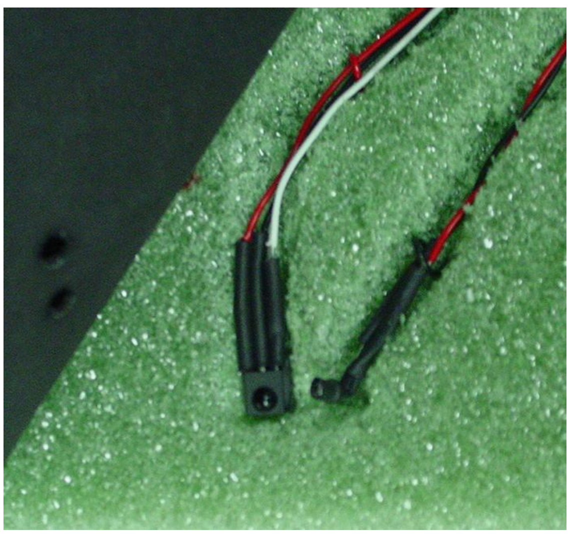
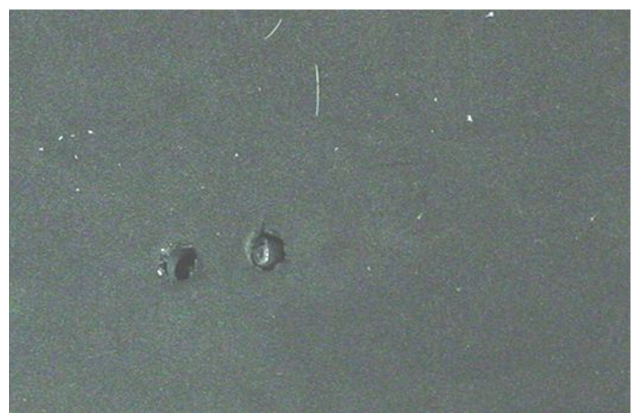


Figure 22—The North-South Intersection and its East-West counterpart.





Figures 23a and 23b

23a—IR LED's and photodetrectors as the lay embedded side-by side under the artifical roadway.; 23b—The IR devices as seen side-by-side through the artificial asphalt.

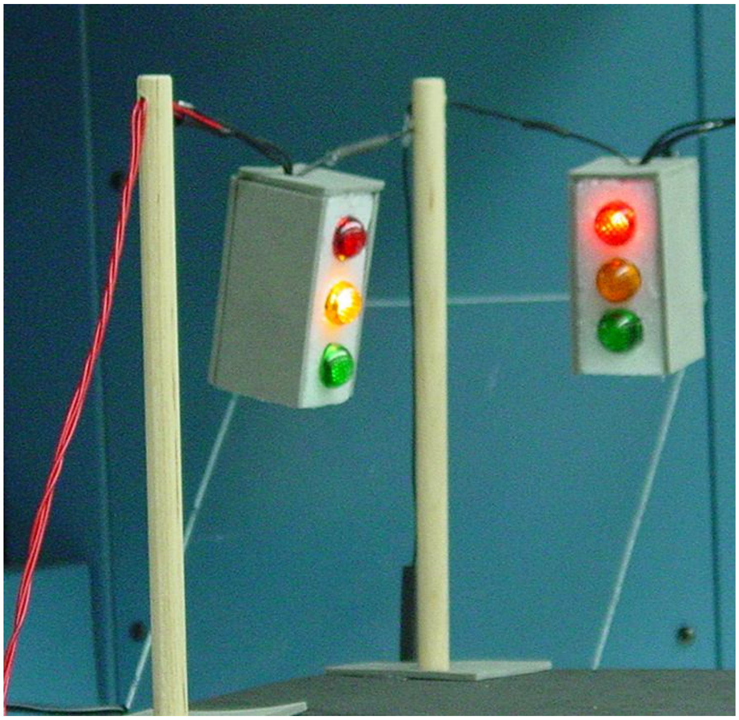


Figure 24--The paradigm in action without any vehicles present. The traffic lights cycle without any changes whatsoever.

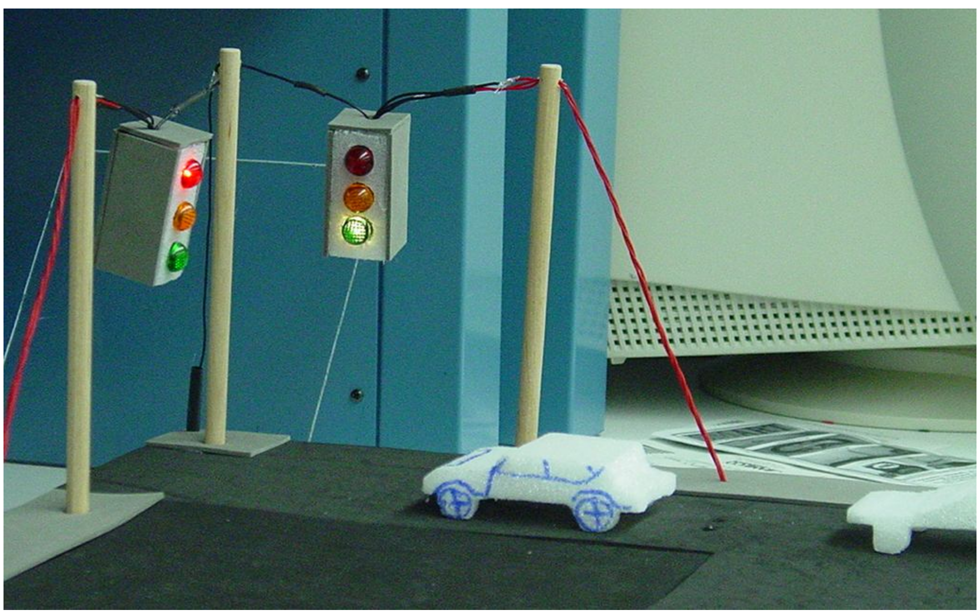


Figure 25--The paradigm in action with vehicles present. The traffic lights now cycle with change.

Conclusions

Light sensors provide a sensitive measurement of light and are often used as non-intrusive motion sensors. Infrared detectors can be used to determine (Fattah 2003):

Once detection takes place, positive feedback takes place. This control loop translates into the regulation of the traffic control lights:

- the entire is adjusted is adjusted
- the duration of the green signal is lengthened depending on the number of vehicles waiting at red light
- the total length of the green light / yellow light is a function of the length of the vehicles lined up at the intersection

The model that has been created in our virtual intersection can be extended to real world traffic intersections either in:

- variably-sized cities, urban or suburban
- streets
- street-highway highway-highway junctions

When the numbers and types of sensors is chosen to fit the particular nuances of the roadways under consideration, the types of problems that can be dealt with is limitless (Fattah).

One of today's most serious social, economical and environmental problems is traffic congestion. on highways as well as inner-city streets and intersections. In addition to the financial cost of the problem, the number of traffic related injuries and casualties is very high. An *Automated Highway Systems* (AHS) has been discussed by both governments: local, state, and federal (Fattah). The *AHS* represents the interplay between modern sensor technology and the current interstate highway system. It utilizes both intelligent vehicles and smart highways. The AHS is slated to consist of high speed communication, vehicle control and traffic management techniques to provide safe, fast and more efficient surface transportation. A key factor in AHS deployment is the implementation of roadway sensors (Bishop, 2001). The implementation of an AHS would require the inclusion of hardware both in the vehicles and in the roadway infrastructure. The latter would include roadside monitors that will: measure traffic flow, patterns of vehicular traffic volume, vehicle speed, vehicular routes, heavily trafficked intersections, and ways to prevent gridlock in vehicle-intense urban centers (Bishop).

Using IR Sensors as Part of an Array

As is the case with other kinds of sensors, IR sensors have a number of functional constraint associated with them. These may result in sensing errors, either: false positive or false negatives. How close the objects being sensed are from the photo detectors is a prime example. The lens focal distance can be selected as a function of the sensor dimensions and the required field of vision (Dehaeck, et al. 2004). So the IR sensor's lens has a major impact on the sensor's sensitivity—the pixel's response to a given radiated power from an object. In addition, the quantity of direct, indirect and ambient IR energy also may lead to errors in sensing (Dehaeck, et al.)

Optical aberrations are caused by imperfections in the lens. The material properties of the lens may result in chromatic and thermal aberrations, so the lens material used is important. For imaging purposes, a plastic lens may do, but for high-accuracy temperature measurements Dehaeck, et al.).

Depending on the environmental situation and application, arrays of land-based optical, thermal, and acoustic-seismic sensor arrays that can interface with one another and the microcontrollers insure the optimal sensing of images, objects, etc. (Navigation & Space Sensors Division (Northrop Grumman), 2003) The limitations of each may be negated by the advantages of the others.

Follow-up Studies

Integrating IR Sensors with a Microcontroller: Automated Regulation of Traffic Flow epitomizes what Mechatronics is truly supposed tobe since it is an synergistic integration of:

engineering-both mechanical and elctrical

computer science

electronics

to manage a civil engineering system. The plan and performance of this particular mechatronic system is paradigm of of dynamic system that models the interface of several electrical circuits and sensors, and signal conditioning , actuators and power electronics, hardware interfacing, rapid control prototyping, and embedded computing.

The logical follow ups to this *mechatronics project would* be:

- increase the diversity and position of sensors at intersections to count and describe in other ways the type of vehicles present
- employ sensors on roadways and highways to:
  - (1) adjust distances between vehicles
  - (2) change vehicle speed
  - (3) communicate with vehicles regarding itinerary depending on other vehcile traffic, weather, etc.

Project Budget—Cost Analysis

PARTS LIST: Integrating IR Sensors with a Microcontroller: Automated Regulation of Traffic							
Description	Qty	Dist.	Part Number	Mfr. Cross Ref. No.	Unit Cost	Unit Size	Total Cost
LED Red, T1, .17"H	**2**	**Jameco**	**206498CD**	**LRY2041**	**0.15**	**(pk 10)**	**0.15**
LED Yellow, T1, .17"H	**2**	**Jameco**	**206480CD**	**LVY2041**	**0.15**	**(pk 10)**	**0.15**
LED Green, T1, .17"H	**2**	**Jameco**	**175679CD**	**LTL-232**	**0.15**	**(pk 10)**	**0.15**
Infrared Emitter Diode (GaAs), T1, .2"D	**4**	**Jameco**	**112150CD**	**TLN100**	**0.24**	**1**	**0.96**
Infrared Receiver	**4**	**Parallax**	**350-00014**		**3.95**	**1**	**15.80**
Relay,DIP,DPDT,5VDC,2A Cont	**6**	**Jameco**	**139977**	**RSB-5-S**	**2.49**	**1**	**14.94**
Diode,Sil Red,1N4001,1A, 50V PRV (10)	**6**	**Jameco**	**35975**	**1N4001**	**0.03**	**1**	**0.18**
Transistor ,2N3904, NPN, GP	**7**	**Jameco**	**38359**	**2N3904**	**0.09**	**(pk 10)**	**0.90**
Resistor,1/4W 5%,1.0K Ohm	**10**	**Jameco**	**29663CD**	**-**	**0.99**	**(pk 100)**	**0.99**
Lamp, Panel, Red, 12 V W/100mm Wire, W/Bulb	**2**	**Jameco**	**215773CD**	**R9-46B-W100-12-R**	**1.79**	**1**	**3.58**
Lamp, Panel, Yellow, 12 V W/100mm Wire, W/Bulb	**2**	**Jameco**	**21581CD**	**R9-46B-W100-12-Y**	**1.79**	**1**	**3.58**
Lamp, Panel, Green, 12 V W/100mm Wire, W/Bulb	**2**	**Jameco**	**215790CD**	**R9-46B-W100-12-G**	**1.79**	**1**	**3.58**
Trans,Wall,12VDC/500mA,F2, 2.1mm x 5.5mm	**1**	**Jameco**	**102496CD**	**EVERDCU120050**	**4.95**	**1**	**4.95**
Bread Board, 2 bus strips, 630 pt, base	**2**	**Jameco**	**20722CD**	**JE23**	**8.95**	**1**	**17.90**
Switch, DPST on-off, 6 pin	**1**	**Jameco**	**158060CD**	**JKN32**	**1.15**	**1**	**1.15**
Jack,DC Pwr,Male,2.1mm, SE Term,PC Mount	**1**	**Jameco**	**101178CD**	**PP014**	**0.49**	**1**	**0.49**
Resistor,1/2W 5%,470 Ohm	**4**	**Jameco**	**107537**	**2R470/100**	**0.99**	**(pk 100)**	**0.99**
Voltage Regulator, 5V, Monolithic, 3-terminal, Pos.	**1**			**LM340T-5**			
Voltage Regulator, 12V, Monolithic, 3-terminal, Pos.	**1**			**LM340T-12**			
Resistor,1/2W 5%,220 Ohm	**1**	**Jameco**	**107490**	**-**	**0.99**	**(pk 100)**	**0.99**
Collectible Penny Racer Cars	**1 Set**	**iQVC**	**T18834**		**13.63**	**1**	**13.63**
Misc. Construction Materials (styraphome, felt & etc.)							**20.00**
						Total Cost	**$105.06**

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We would like to thank SMART Project Director Professor Vikram Kapila, Project Instructor Sang-Hoon Lee, Project Assistant Anshuman Panda, Graduate Student—Jon Blyer, and the rest of Polytechnic University's Mechanical Engineering Department for their assistance and patience. We would also like to thank Professor Noel N. Kriftcher and Alessandro Betti for their consultative assistance and/or support.

Parenthetically, we would like to thank Parallax, Inc. for donating a "Homework Board", and a "What's a Microcontroller" text and parts kit to each teacher involved in the project and Polytechnic University and the National Science Foundation for making this program possible.

Appendix A-PBASIC Programs

```
' {$STAMP BS2}
' {$PBASIC 2.5}

'-----------------------------------------------------------------------------------------
' "Intergrating IR Sensors with a Microcontroller: Automated Regulation of Traffic Flow"

' A Mechatronics Demonstration Project" This work was supported by the National Science
' Foundation under an RET Site Grant 0227479.

' Project by:
'   Michael Koumoullos
'     Aviation High School
'     Long Island City, NY 11101
'          &
'   Robert H. Winston
'     Canarsie High School
'     Brooklyn, NY 11236

'-----------------------------------------------------------------------------------------

' Pins 0-3 are set as input pins.  They are connected to the IR photosensors.
' Pins 0 is near the intersection on the NS road.
' Pins 1 is far from the intersection on the NS road.
' Pins 2 is near the intersection on the EW road.
' Pins 3 is far from the intersection on the EW road.

INPUT 0
INPUT 1
INPUT 2
INPUT 3

' The variables pin0-pin3 represent the input signals coming from pins 0-3.
' They are of bit size because they can only return two conditions: 1 if not covered by
'   a vehicle and 0 if covered by a vehicle.

pin0 VAR Bit
pin1 VAR Bit
pin2 VAR Bit
pin3 VAR Bit

' Variables x and y are multiplied by a constant of 2 seconds to determine the length of
'   the green light for the NS and EW streets, respectively.
' The size Nib is used because it supports upto 16 characters.  Variables x and y can
'   only be returned as 6, 3 or 1.
```

```
x VAR Nib
y VAR Nib

main:

' FREQOUT sends a signal out of pin 4, through a transistor to the IR LEDS on the NS road.

FREQOUT 4,1, 36000
pin0 =  IN0

FREQOUT 4,1, 37000
pin1 =  IN1

' DEBUG displays the condition of the two infrared sensors at the moment the Basic Stamp
'   checks to determine the duration of the NS green light.

DEBUG HOME, ? pin0, ? pin1

' The variable x is set equal to 1.  If neither of the two conditions below are met, the
'   value of x will stay at 1 and the duration of the green light on the NS road will be
'   (1*2000 mil sec) 2 seconds.

 x=1

' If the rear sensor is covered (Pin 1) then x=6.  This means that the duration of the green
'   light will be (6*2000 mil sec) 12 seconds.

  IF PIN1=0 THEN
   x=6

' IF Pin 1 is not covered, the Basic Stamp will run the ELSEIF command below.  If the sensor
'   near the intersection is covered, the duration of the green light will be (3*2000 mil
'   sec) 6 seconds.

  ELSEIF PIN0=0 THEN

   x=3
  ENDIF

'-----------
' LOW 10 = EW red light turns off
' HIGH 12 = EW red light turns on
' Pause is determined by the value of x as indicated directly above.
```

```
LOW 10
HIGH 12
PAUSE x*2000

' LOW 12 = EW green light turns off
' HIGH 11 = EW yellow light turns on
' Pause is for 2 seconds.

LOW 12
HIGH 11
PAUSE 2000

' LOW 11 = EW yellow light turns off
' HIGH 10 = EW red light turns on
' Pause is for 2 seconds (double red light).

LOW 11
HIGH 10
PAUSE 2000

'-----------

' FREQOUT sends a signal out of pin 6, through a transistor to the IR LEDS on the EW road.

FREQOUT 6,1, 38000
pin2 =  IN2

FREQOUT 6,1, 39000
pin3 =  IN3

' DEBUG displays the condition of the two infrared sensors at the moment the Basic Stamp
'   checks to determine the duration of the EW green light.

DEBUG HOME, ? pin2, ? pin3

' The variable y is set equal to 1.  If neither of the two conditions below are met, the
'   value of y will stay at 1 and the duration of the green light on the EW road will be
'   (1*2000 mil sec) 2 seconds.

  y=1

' If the rear sensor is covered (Pin 3) then y=6.  This means that the duration of the green
'   light will be (6*2000 mil sec) 12 seconds.
```

```
IF PIN3=0 THEN
  y=6

' IF Pin 3 is not covered, the Basic Stamp will run the ELSEIF command below.  If the sensor
'   near the intersection is covered, the duration of the green light will be (3*2000 mil
'   sec) 6 seconds.

 ELSEIF PIN2=0 THEN
  y=3

 ENDIF

'-----------
' LOW 7 = NS red light turns off
' HIGH 9 = NS green light turns on
' Pause is determined by the value of y as indicated directly above.

LOW 7
HIGH 9
PAUSE y*2000

' LOW 9 = NS green light turns off
' HIGH 8 = NS yellow light turns on
' Pause is for 2 seconds.

LOW 9
HIGH 8
PAUSE 2000

' LOW 8 = NS yellow light turns off
' HIGH 7 = NS red light turns on
' Pause is for 2 seconds (double red light).

LOW 8
HIGH 7
PAUSE 2000

'-----------

GOTO main

END

' We would like to express our deepest gratitude for all the assitance and guidance provided
```

```
' to us by Project Director Professor Vikram Kapila, Project Instructor Sang-Hoon Lee and
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```

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