Continental J. Engineering Sciences 3: 56 - 63, 2008

A MICROCONTROLLER-BASED HIGHWAY-RAILWAY LEVEL CROSSING TRAFFIC CONTROLLER

J. A. Enokela[1] and E.J. Ibanga [2]
[1]Department of Electrical Engineering, University of Agriculture, P.M.B 1273, Makurdi, Nigeria
[2]Department of Physics, Nasarawa State University, P. M. B. 1022, Keffi, Nigeria.

ABSTRACT
Highway-railway level crossings across the country have witnessed a number of fatal accidents in the past. Many of the level crossings in the rural areas are not protected by level crossing gate signals. In the urban areas where these provisions are put in place, the operation of the level crossing gate is usually entrusted to the level crossing keeper- who opens and closes the gate against road traffic at times that he deems necessary. This results in the closing and opening of the gate earlier or later than necessary as well as the intervention of a human superintendent who may not be on duty at the correct time. These factors cause difficulties and possible accidents for the highway/railway users. This work describes a control system that uses a microcontroller to handle traffic flow across a major and typical highway-railway level crossing located in an urban centre. It is seen that the incorporation of computer methods into the operation of the level crossing improves its safety, speed and reliability.

KEYWORDS: Highway, Railway, level crossing, control, traffic, microcontroller,

INTRODUCTION

Highway-Railway level crossing traffic signal controls in the country have traditionally been operated by level crossing keepers who use flags and signal lamps mounted on gates to warn highway users of the approach of a train. These keepers, on sighting a train, physically close the railway gate against road traffic until the train has passed after which the gate is opened (Nigerian Railway Corporation: General Rules, 1979) . This traditional method is very much dependent on the human factor and has important shortcomings:

(i) There is no preemption in the system to alert the highway users of the approach of a train before the railway gate is closed against the road traffic.
(ii) The gate is generally closed against road traffic for a longer period than absolutely necessary to secure the safety of the public and train.
(iii) The entire operation depends on the level crossing keeper who may not show up for his duty on time as has been known to happen especially in poor weather conditions.

These shortcomings have led to lots of inconvenience for both the railway and highway users as well as the occurrence of accidents on such level crossings.

Traffic controls at level crossings are generally required to have some form of preemption. This is the transfer from normal operations of signals to a special control mode. Rail traffic preemption often occurs when a train approaches highway-rail grade crossings (Metrolinks Ttrain, 2004 and Institute of Transport Engineers, 2004).

Preemption defines various times and these include:

(a) Advanced Preemption time which is the notification of an approaching train that is forwarded to the highway traffic signal controller unit for a period of time prior to activating the railway active warning devices.
(b) Pedestrian Clearance time is the time provided for a pedestrian crossing on a crosswalk after leaving the curb or shoulder, to travel to the centre of the farthest traveled lane or to a median. At a normal walking speed of at least 1.2m/s the walk interval should be at least 7 seconds.

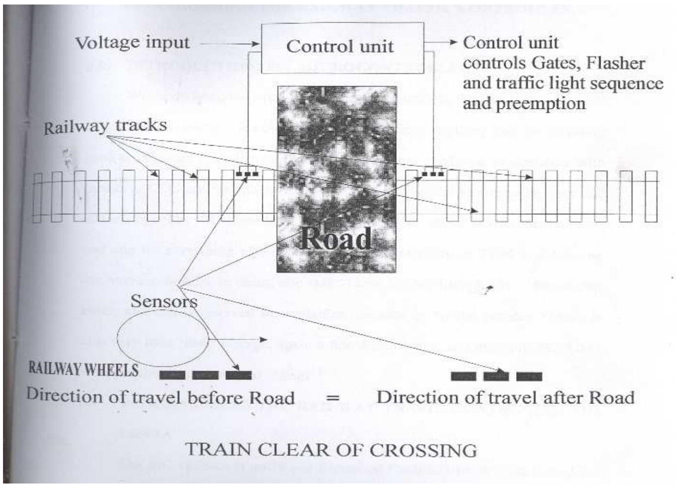

Figure 1: Traffic control System (Enokela and Ogah, 2005).

(c) Queue Clearance time is the time required for the design vehicle stopped within the minimum track clearance distance to start up and move through the minimum track clearance distance.
(d) Minimum Warning time is the least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossing.

The knowledge of these times are necessary to enable us calculate the length of time required for the gate to be closed against the road traffic (Institute of Transport Engineers, 2004). The effective time that the crossing would be blocked by a train can be estimated from equation (1)

$$r = 35 + \left(L / 1.47s \right) \cdots\cdots (1)$$

Where;

L = train length and
s = train speed.

The factor of 35 assumes approximately 25 seconds before the train enters the crossing plus 10 seconds after it clears the crossing that the crossing would still be blocked by gates. These times may be adjusted us necessary for individual crossings (Institute of Transport Engineers, 2004). Various methods have been used to design traffic controllers at highway-railway level crossings (K.L.E. Society's Polytechnic, Hubli, 2003; James David Chapman's web site, 2004; and Goja, and Orhungur 2004). This work uses a microcontroller for the design of the traffic controller. The advantages of this method include low power consumption since less hardware is required, and a high reliability that is comparable to that achievable using a full-scale microprocessor.

MATERIALS AND METHODS

The traffic controller has been designed using the Microchip's PIC18F2585 microcontroller. This microcontroller has up to 48K bytes of flash program memory space, 4K bytes of RAM as well as 1K bytes of EEPROM. It also features a CPU having a standard set of 75 instructions (Microchip Technology Inc. 2004). The design was done in 2005 at the Electronics Laboratory, University of Agriculture, Makurdi, Nigeria.

System Operation

The traffic controller system that has been developed is indicated in figure 1 (Enokela and Ogah, 2005). The system consists of two sensors placed 1000m apart, one on each side of the road. The sensor employed is a simple dc type which operates such that a train on the section of the affected track will trigger the switch thus generating an interrupt for the control unit circuitry. The control unit then enters the preemption mode. Visual and audible warning signals are sent out to alert the highway users of the approach of a train. The visual signals consist of red, yellow, and green lights mounted on the gate while the audible signal is a loud siren. Once the approach of a train has been detected, the control unit

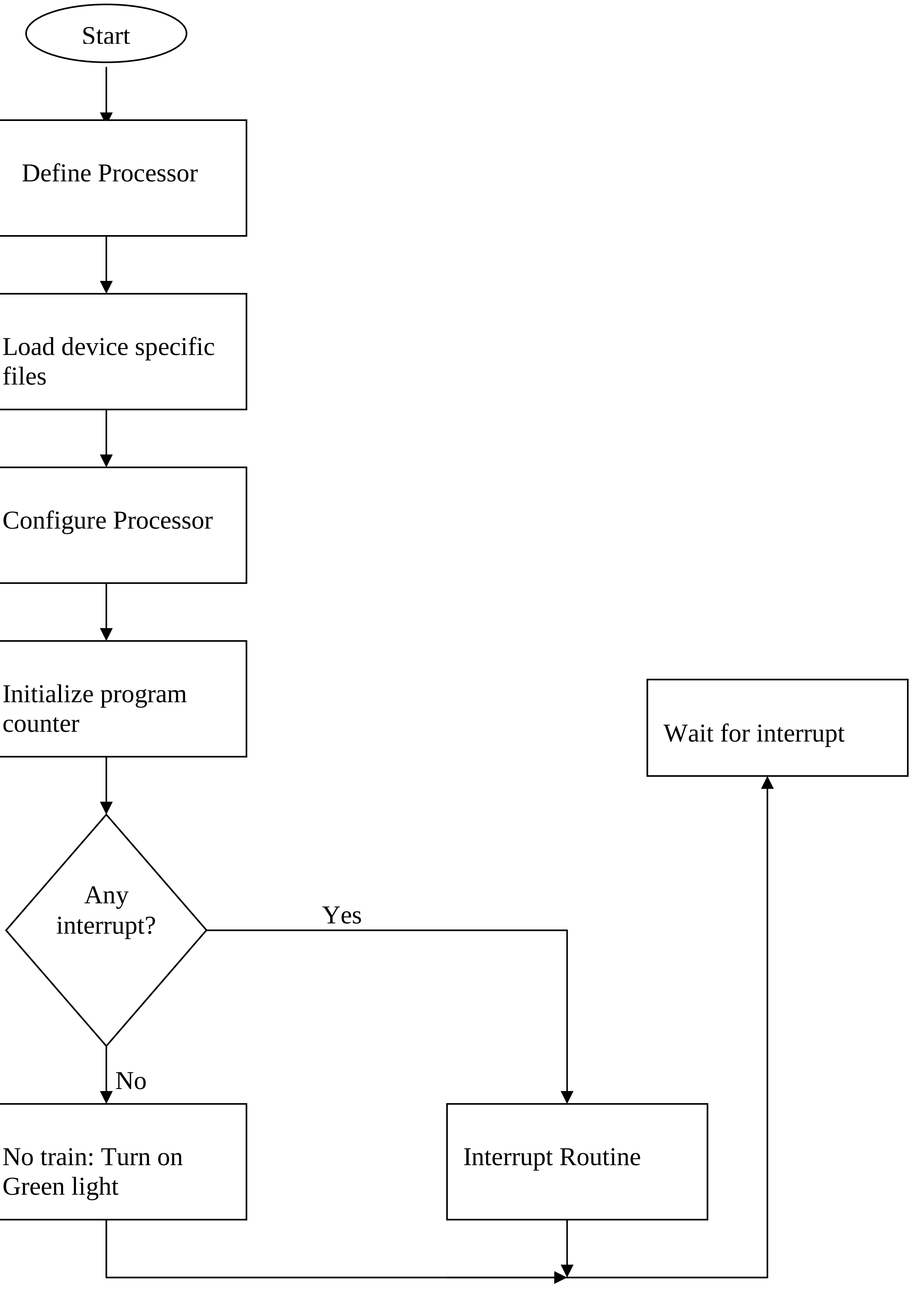

Fig. 2: Flow Chart for Traffic Controller

triggers a siren and the yellow light is activated for 20 seconds so that all road users will have adequate time to cross the rail. This period represents the warning time. Warning times should not exceed 40-50

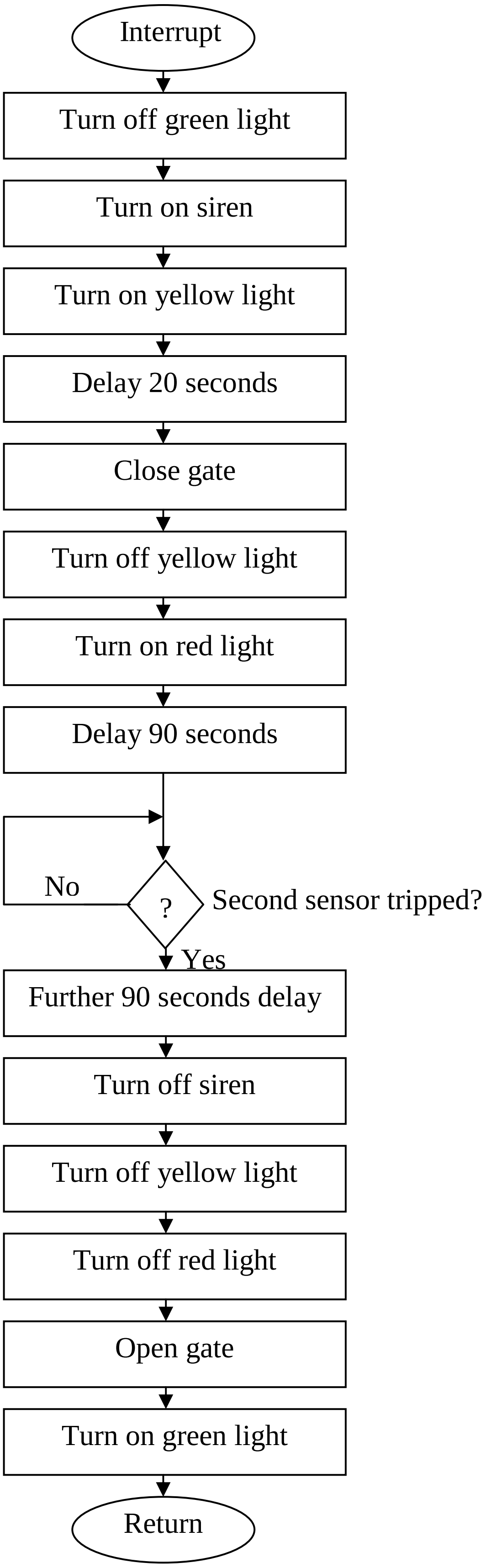

Fig. 3: Interrupt Service Routine

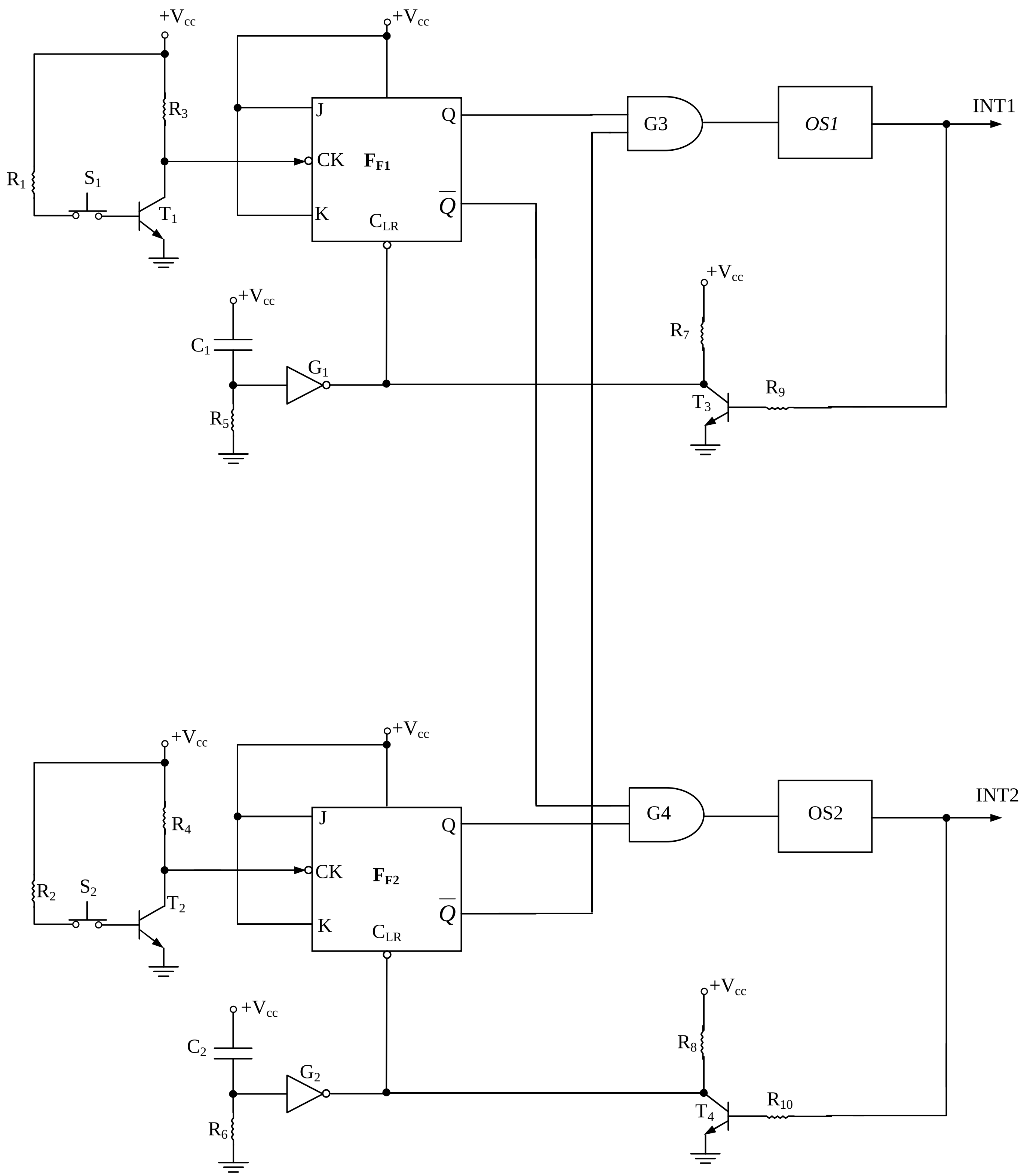

Fig. 4: Sensor and Interrupt Control Circuit

seconds so that undesirable driver behaviour such as attempting to drive around gates can be avoided (Federal Highway Association, 2004).

At the expiration of the warning time the gates are closed against road traffic and the warning light turns red. The audible signal is still turned on. The gate remains closed against road traffic for a period

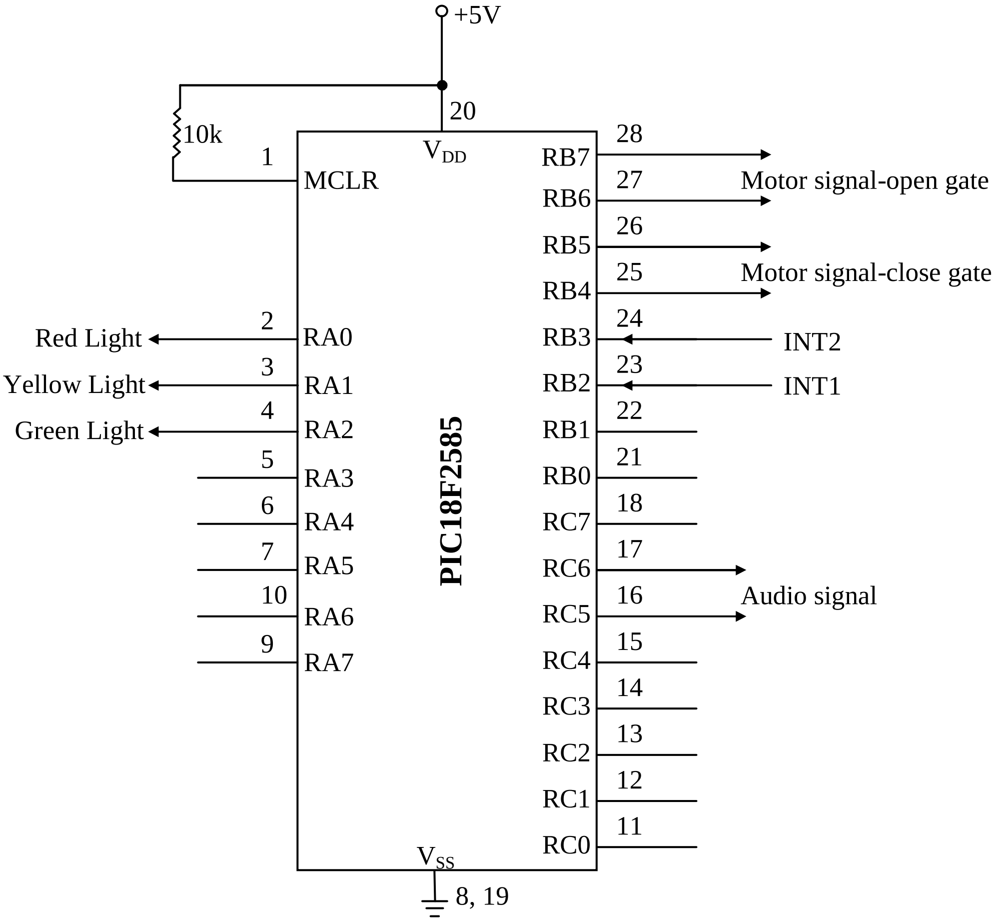

Fig. 5: Traffic Controller Circuit Showing Various Control signals

determined approximately by equation (1). When the train triggers the second sensor the gate light turns yellow for 20 seconds after which the gate opens and the gate light turns green. The audible signal turns off thus completing the cycle.

Program Developments

The global flow chart for the traffic controller is indicated in figure 2. The program has been developed using the assemble language. The processor used is defined in accordance with the assembler (Microchip Technology Inc. 2005a). The processor's specific files are loaded and the processor is appropriately configured. The program then goes into an infinite loop while checking for interrupts. In the absence of a train the green light at the gate is turned on and the gate is opened to road traffic. The arrival of a train is acknowledged by the generation of an interrupt signal from the sensor.

Various events occur in the interrupt routine (figure 3). These consist of turning on the siren and the yellow traffic light to warn the highway users of the approach of a train. This is followed by a 30-second warning time to enable all road traffic to clear off the railway. The gate is then closed against road traffic and the red light is turned on. The control system goes into a delay mode to allow the train to pass. When the train trips the second sensor there is a further delay to allow the last train coach to pass through the gate which opens thereafter. The siren is then turned off while the green light is turned on to indicate the "all clear" for the road users. It should be observed that once the first sensor from either direction has been tripped and the gate closed, the gate will remain closed indefinitely until the second sensor from either direction is tripped. This situation allows for a train to stop between the sensors after tripping the first sensor from either direction.

Hardware Design

The sensor and interrupt control circuit is given in figure 4. The flip-flops FF1 and FF2 are configured as T-type (Hill and Peterson 1981) and are cleared (Q = 0) at power on. This condition is assured by the power-on reset circuits G_1 and G_2. When the train wheels march the sensor switch S_1 the flip-flop FF1 is clocked and the one-shot circuit (OS1) fires a pulse which constitutes the interrupt INT1 for the processor. INT2 is generated in a similar manner. If INT1 occurs first while INT2 occurs later then INT1 controls the turning on of siren, yellow light, closing of gate and turning on of red light while INT2 turns off the siren, the yellow light, the red light, opens the gate and turns on the green light. However if INT2 occurs first the roles are reversed. This behaviour of the system is accomplished in software. The question of whether INT1 or INT2 occurs first depends on the direction of approach of the train.

The microcontroller connection showing various control signals at the I/O pins is shown in figure 5. The interrupt signals (INT1, INT2) are inputs to the microcontroller while the other signals are output from the microcontroller and are used for various control functions.

RESULTS AND DISCUSSIONS

The program for the traffic controller was written with the aid of Microchip's MPLAB IDE version 7.50 (Microchip Technology Inc. 2005b). After assembling the program, software simulation was carried out and the program was comprehensively debugged using the MPLAB IDE's simulator. The components were then wired together in software environment using the NI Multisim Circuit Design suite version 10.0.1 (National Instruments, 2007). Normal operation of the circuit without interrupts was observed. The circuit was interrupted by operating the switches S_1 and S_2 and the sequence of lighting of the LEDs connected to the port pins was observed to be correct. LEDs were used in place of the motor drive signals. The circuit was then built on a circuit board with the components properly soldered together. The hexadecimal (hex) file generated from the assembly process was transferred into the program memory of the microcontroller with the aid of the MPLAB In-Circuit Debugger MPLAB ICD2 (Microchip Technology Inc. 2005c) and a hardware simulation was carried out to observe the performance of the physical circuit. Once more light emitting diodes were used in place of the motors. The lights turned on and off as desired.

CONCLUSION AND RECOMMENDATION

A highway–railway level crossing traffic controller that operates without the intervention of a human gate keeper has been designed and implemented. The design has utilized a microcontroller for cost effectiveness. The traffic controller can be interfaced with a high-powered motor required to operate the gate and an audio system that would put out a loud warning signal.

REFERENCES

Enokela, O.K, and Ogah, D.A. (2005) "Design and construction of a microprocessor based railway traffic controller", B.Eng. Thesis, University of Agriculture, Makurdi, unpublished.

Federal Highway Association, (2004), "Guidance on traffic control devices at highway-rail grade crossings", Executive summary, www.safety.fhwa.dot.gov/media

Goja, A.J. and Orhungur, M. (2004) "Design and construction of a traffic control system at a railway crossing", B.Eng Thesis, University of Agriculture, Makurdi, , unpublished.

Hill, F.J., and Peterson, G.R (1981) Introduction to switching theory and logical design, John Wiley and Sons, New York, 3/e, 1981.

Institute of Transport Engineers, (2004), Preemption of traffic signals near railroad crossings, www.ite.org/standards.

James David Chapman's web site, (2004) "Traffic light project", www.users.gloalnet.co.uk/~jchap

K.L.E. Society's Polytechnic, Hubli, (2003), Microprocessor based railway control system, www.vidyapatha.com/student.proj/electronics.

Metrolinks train, (2004), Preemption guidelines for highway–rail grade crossing, www.metrolinkstrains.com.

Microchip Technology Inc. (2004) Data Sheet PIC18F2585/2680/4585/4680, 2355 West Chandler blvd., Chandler, Arizona.

Microchip Technology Inc (2005a) MPASM Assembler, MPLINK Object Linker, MPLIB Object Librarian User's Guide, , 2355 West Chandler blvd., Chandler, Arizona.

Microchip Technology Inc. (2005b), MPLAB IDE User's Guide, , 2355 West Chandler blvd., Chandler, Arizona.

Microchip Technology Inc (2005c), MPLAB ICD 2 In-Circuit Debugger User's Guide, 2355 West Chandler blvd., Chandler, Arizona.

National Instruments (2007), Multisim user guide, 11500 North Mopac Expressway, Austin, Texas.

Nigerian Railway Corporation: General Rules, 1964, (as amended in 1979), Re-printed by the Railway Press, Ebute-Metta, Lagos.

Received for Publication: 07/05/2008
Accepted for Publication: 25/05/2008

Corresponding Author:
E.J. Ibanga
Department of Physics, Nasarawa State University, P. M. B. 1022, Keffi, Nigeria.
E-mail: enojamesibanga@yahoo.com