ON THE ELECTRONIC SIGNAL DIRECTION INDICATOR FOR THE CONTROL OF ROAD TRAFFIC

M. U. Onuu and P. I. Nkanu
Department of Physics, University of Calabar, Calabar, Nigeria
E-mail: michaelonuu@yahoo.com

(Submitted: 14 February, 2006; Accepted: 3 April, 2006)

Abstract

An electronic signal direction indicator (ESDI) for the control of road traffic has been designed, constructed and studied. The construction was done using 555 timer IC, a transistor-transistor logic compatible device that can operate in several modes as the major active element. The ESDI system circuit is reliable, satisfactorily operational and meets the standards of World's Insurance Institute for Highway Safety as experimental results are in good agreement with those obtained from theory.

***Keywords**: Electronic signal direction indicator, road traffic, highway safety.*

1. Introduction

One of the most important factors in road safety is a system of traffic control. The world's first traffic light came into being before the automobile was in use (Chappe, 1857). During the past 10 years, automobile control technology has advanced rapidly due to various and more stringent quality design standards set by World's Insurance Institute for Highway Safety (WIIHS).

There are all sorts of technologies for automobile traffic control. By far the most reliable technique is the one that operates on timers. Electronic Signal Direction Indicator (ESDI) which is a system for controlling the movements of traffic within a control zone (roundabout) is one of the devices usually employed to control traffic. It keeps road traffic flowing smoothly and thus maintains free-flow of traffic, for example, in a T-junction (Fig. 1) ESDI as a decision maker, plays a central role in preventing collisions of automobile vehicles in congested areas, particularly at roundabout, where the road is full of automobile vehicles of different types and sizes travelling at various directions and speeds.

According to Cavendish (1938), the ESDI is a circuit capable of producing accurate and repeatable oscillations or delays. Basically, operation allows the timing to be figured through IC, flip-flop, transistors, capacitors and resistors. The system is dependent on power, voltage and timing and is mainly based on the principles of multivibrator (Robert, 1997) a relaxation oscillator. It is a digital logic device whose output can be either a high voltage (signal) level or a low voltage level. That is, it will either be set or reset, and the state of the output can be changed with proper input signals.

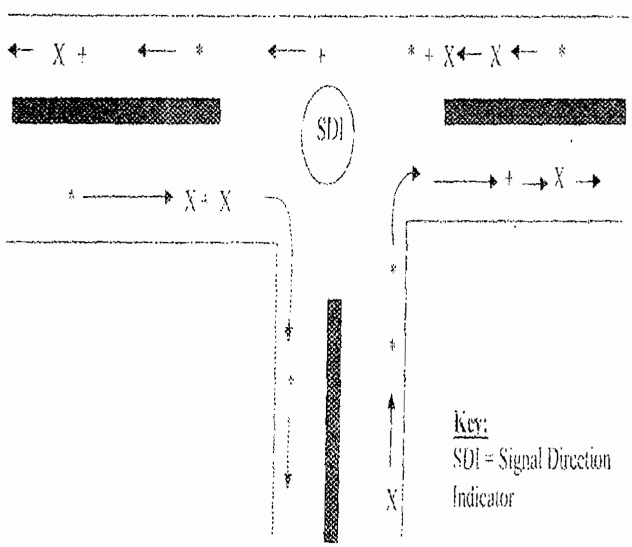

Fig. 1. Model of a T-junction showing types of vehicles

Many traffic control systems currently in use are not reliable, are expensive and are characterised by poor efficiency. The objectives of this research are therefore to design and construct a system that is reliable, efficient, cost effective through application of knowledge and skill for continuous control of traffic flow that will ensure safety of motorists.

2. Theory

The output of the 555 timer IC (the astable multivibrator) used in this investigation is a repetitive regular waveform that switches between two logic levels with the time intervals at each logic level determined by the values of R and C. The length of time it takes for the external capacitor to change determines the time interval that the output is high. Thus, the external time constant, $(RC)_{ext}$. sets the width of the output pulse. The duration of unstable state is given, approximately, by the time constant (Rhys, 1983).

$$t = \log_e(2RC) = 0.931RC \qquad (1)$$

so that the natural frequency, f_o, of the astable circuit is given by

$$f_o = \frac{1}{06931RC} \qquad (2)$$

The external capacitor, C, is initially uncharged but starts charging exponentially with a time constant of RC seconds. When the voltage across C reaches the upper threshold, the flip-flop is set causing the output to go low. This, in turn, causes C to discharge exponentially with a time constant of RC seconds back to the lower threshold. When this threshold is reached, the flip-flop is triggered, causing it to reset and therefore takes the output high. Thus, the cycle commences again and a series of pulses are produced at the output.

Since the time taken to charge C from a lower threshold value ($V_{cc}/3$) to the upper threshold value ($2V_{cc}/3$) is 0.6931 CR and a similar time is taken to discharge C, then the cycle time is approximately 1.39 RC seconds and frequency of oscillation is approximately 0.72/RC Hz. In this circuit, the output is a square wave since the capacitor is charging and discharging into the same resistor.

However, the voltage difference between the upper level of the output and the upper threshold is not exactly equal to the voltage difference between the lower threshold and lower level of output; and the output remains in the high state longer than in the low level state. This situation is corrected by the addition of a resistor R_2 between the positive supply rail (V_{cc}) and the junction of trigger input and the threshold input. The extra resistor allows the timing capacitor to charge up to the full supply voltage and thus makes the voltage difference between the lower threshold and lower level of output.

With power applied, trigger and threshold inputs are both below $V_{cc}/3$ and the timing capacitor is uncharged. The output voltage is high and stays high for a period given by (Calcutt, 1994):

$$t_1 = 1.1C(R_1 + R_2) \qquad (3)$$

where t_1 is in seconds. Eqn.(3) expresses the initial charging time taken by capacitor C to reach the upper threshold value of $2V_{cc}/3$. The flip-flop is triggered and the capacitor will then begin to discharge through resistor R_2, which takes a time, t_2, given by

$$t_2 = 0.93R_2 \qquad (4)$$

Where t_2 is in seconds. Therefore, the total time required to complete a charge and discharge cycle is

$$T = t_1 + t_2 = 0.6931C(R_1 + R_2) \qquad (5)$$

and the frequency of oscillation is

$$f = \frac{1.44}{c(R_1 + 2R_2)} \qquad (6)$$

The graph of this astable multivibrator circuit showing free-running frequency values for specified component values has been drawn (Calcutt, 1994).

Equations expressing T_{high} and T_{low} are given as (Robertm, 1997)

$$T_{low} = 0.7(R_2)C \quad (7)$$

and

$$T_{high} = 0.7(R_1 + R_2)C \quad (8)$$

It should be noted that R_1=R_2 (for symmetrical square wave in eqn. (7)) and capacitor C discharges through R_2 at T_{low}. Therefore,

$$T_{total} = T_{high} + T_{low} \quad (9)$$

3. Materials and methods

3.1 Materials

The control elements of the ESDI circuit are the 555 IC timer and 4017 counter/divider as the a stable and bistable multivibrator respectively. They were chosen as the active components because of their versatility and general-purpose nature. Other reasons considered in the choice of the control elements include availability, low cost and easiness to maintain. Other components were chosen based on certain desirable characteristics they possess. For instance, 7812 IC and other semiconductor components were chosen because of their qualities to stabilize the output of the ESDI.

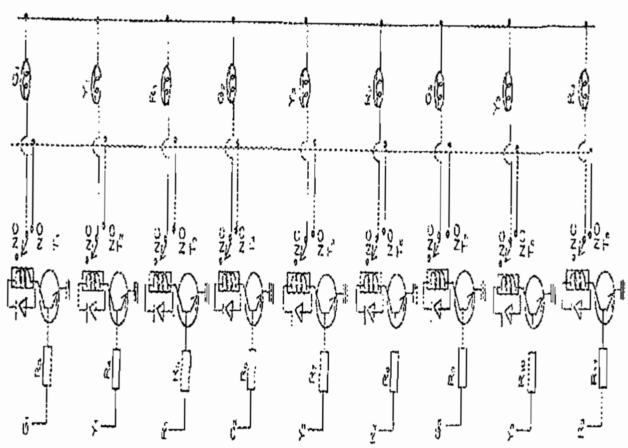

Fig. 2: Circuit diagram of ESDI for road traffic (without power supply)

Some precision testing equipment were used to analyse the circuit and waveforms. They include teleququipment oscilloscope (Type S 51 E). LBO 508A dual trace oscilloscope, digital multimeter (model PD 338) and waveform analyser (Nothingham, manufactured by TQ electronics).

3.2 Methodology

The design of the ESDI was based on the actual values of the components chosen in accordance with certain theoretical calculations to give the required parameters as shown in the theory. Although such calculations usually deviate from practical values, they provide the much-needed insight for starting at the design process. The design and construction of the ESDI circuit were taken stage by state. The four stages (Fig. 2) are: power supply unit (complete rectifier circuit); oscillator (astable multivibrator), counter (bistable multivibrator) and control and transistor (switching circuit).

4. Testing

Testing of the ESDI control circuitry was carried out with the required standard measuring instruments outlined in 3.1. The testing assumed good operation of the system capable of producing repeatable oscillations and time delay. Time periods in microseconds for the ESDI control circuitry and the generated square-wave signals were the facts affirmed by the testing procedures using the calibrated oscilloscope for the measurement of amplitude and time.

5. Analysis, Results and Discussion

5.1 Output signals

The results stated here under show the measured output signals using calibrated scales for measuring amplitudes and time.

A) Voltage

Using an oscilloscope setting of 100mV/cm, the amplitude of the square wave signal was measured. Its peak-to-peak amplitude (Fig. 3) was obtained thus:

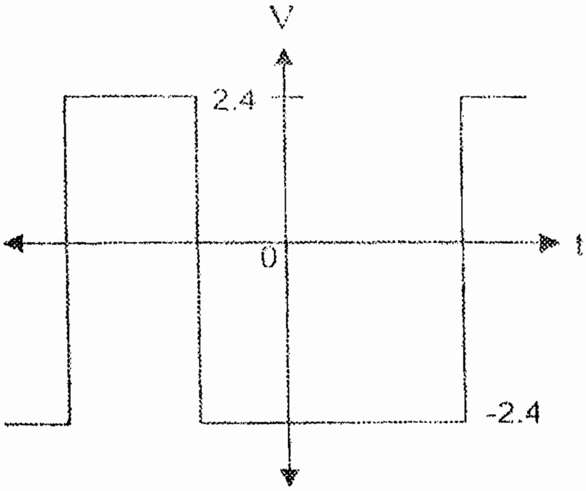

Fig. 3. Showing peak to peak amplitude of the output signal

Vp-p = (2.4cm + 2.4cm) x 100mV/cm
= 480mV
= 0.48V

(b) Period

(i) Experimental

For the measurement of the period, T_1, of the waveform (Fig. 4) oscilloscope setting was at 100s/cm determined thus:

T = 3.45cm x 100s/cm
= 345s
= 0.345×10^{-3}S

Figure 4 shows that the signal was applied as vertical input with horizontal sweep, resulting in an oscilloscope display of the square-wave signal.

(ii) Theoretical

Using eqns. (7)-(9) the calculated data for the period were obtained:

$T_{high} = 0.7 (2.4 \times 10^3 + 2.4 \times 103 (0.1 \times 10^{-6})$s
$= 0.34 \times 10^{-3}$s

$T_{low} = 0.7 R_2 C$
$= 0.7(2.4 \times 103) 0.1 \times 10^{-6})$s
$= 0.17 \times 10^{-3}$s

$T_{total} = 0.34 \times 10^{-3} + 0.17 \times 10^{-3}$s
$= 0.5 \times 10^{-3}$s

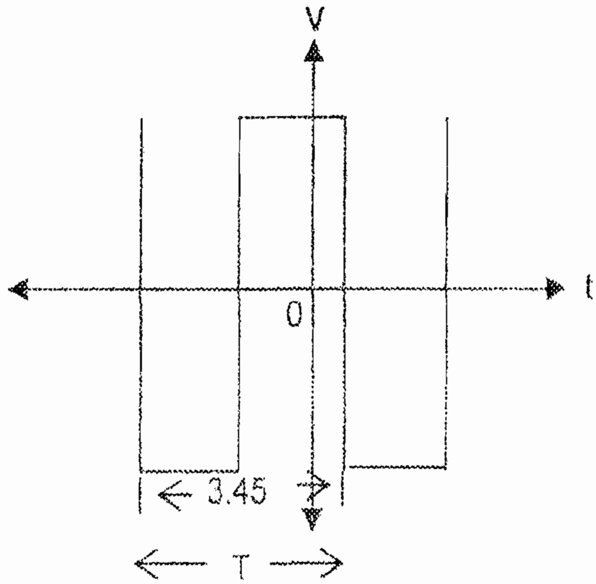

Fig. 4. Showing periods of the output signal

Figure 5 shows (exponential rise and decay) waveform displayed on the oscilloscope showing how C charges and discharges (a) and the experimental square waveform superimposed (b).

From the results, highlight should be made of the close agreement between experiment and theory. For instance, practical component values used in the design of the circuit agreed well with calculated values. The measured amplitude of the square-wave signal was 0.48V while the theoretical value was 0.485V. Also, the period, T_{high}, of the waveform as measured with the oscilloscope was 0.345 x 10^{-3}s while the value was 0.34 x 10-3s when calculated using the values of external resistor and capacitor. The implication is that tolerances of the components and attenuation by the oscilloscope were negligibly small.

Plate 1 shows the output of the ESDI as displayed on the screen of the oscilloscope and the ESDI circuit on a copper strip board mounted on the lower chamber of the cabinet box measuring 0.095 x 0.1 x 0.15m and the constructed 15V d.c dual regulated power supply.

The prototype ESDI with lamps display showing a T-junction on a demonstration board is shown in Plate 2. The device operates satisfactorily well and satisfies the World Insurance Institute for Highway Safety

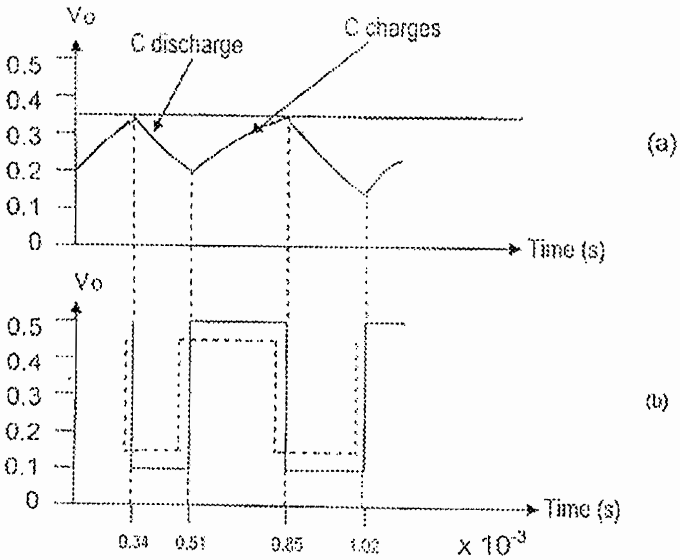

Fig. 5: Output waveforms showing how C charges and discharges (a), and the experimental waveform superimposed (b)

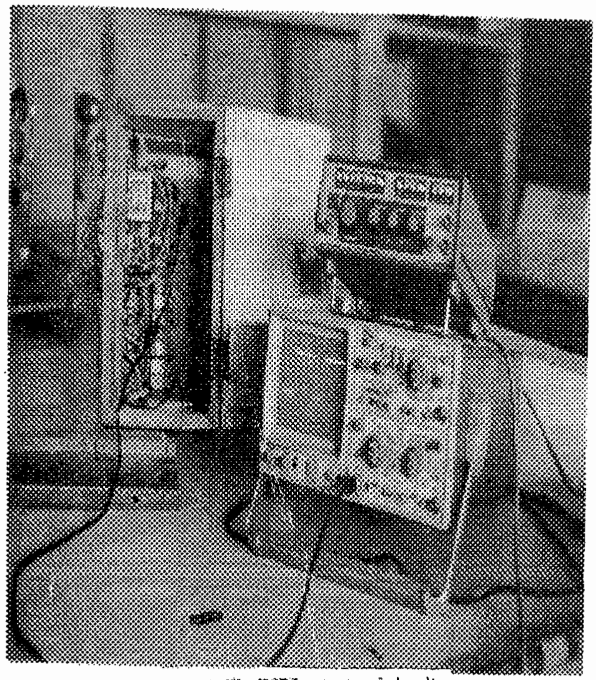

Plate1: The ESDI output and circuit.

(WIIHS) minimum standard of 60s for "go" signal, 30s for "warning" and 120s for "stop" signal at nominal d.c. voltage of 15V. It also meets the international standards established by Federal Highway Administration, U.S.A. for every sign, signal and traffic control signal device to ensure that signs and signals are used in the same manner everywhere in the world.

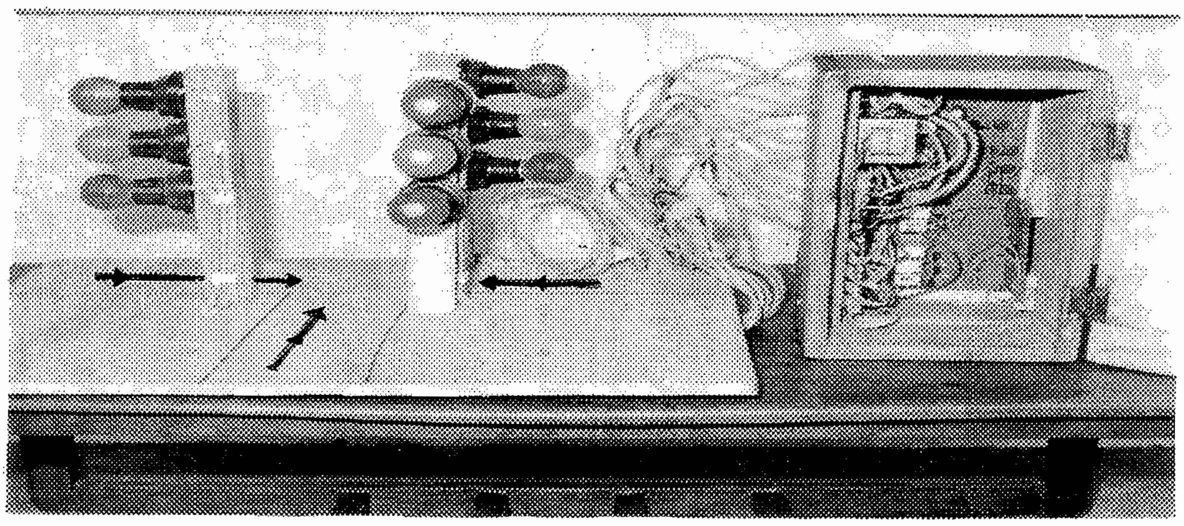

Plate 2: Prototype ESDI with lamps display on a demonstration board

6. Conclusion

The implementation of ICs as an alternative to discrete components in the design of the ESDI has greatly reduced circuit complexity, improved miniaturization and compactness that is the main essence of modern electronics. This has significantly reduced heat dissipation during operation. The designed and constructed ESDI operates satisfactorily well and meets the standards by the World Insurance Institute for Highway Safety (WIIHS) and Federal Highway Administration, U.S.A.

References

Amos, S. W. (1977): Radio TV and Audio Technicl Reference Book, Newnes-Butter, London.

Belts, J. (1970): Signal Processing and Modulation, J. `V. Anowsmith Limited, Great Brita: ı.

Cavendish, M. (1981): I roadcasting and Communicating, ('avendish Books Limited, London.

Chappe, C. (1857): Te'ephone and Cables, Emmission Lin' ted, Ontario.

Ellison, A. J. (197: : Acoustic Noise and Vibration, S: cond Edition, Longman Press, Lond: ı.

Geary, L. (1988). Modern Electronics. Third Editio, Longman, London.

Green, D. C (1982): Electronic Circuits' II, Jo!, -Willey and Sons.

Handel, S. (1971): Electronic Engineers Reference Book, Cox and Wyman Limited, United Kingdom.

Mad ıok, R. J. and Calkcutt, D. M. (1995): Electronics, a Course for Engineers Longman Group Limited, England.

'Aenkiti, A. I. (2000): Logic Circuits, Devices and Applications, EFTIMO (Nigeria) Press, Calabar.

Nathan, L. (1987): Traffic Lights and Roundabout," Love and Malcomson, United Kingdom.

Nkanu, Philip Ina (2004): Design and Construction of Electronic Signal Direction Indicator for the Control of Road Traffic, M.Sc. Thesis, University of Calabar, Calabar, Nigeria.

Pabco, E. C. 91991): Fundamentals of Electronic, Fourth Edition.

Putten, A. P. (1988): Electronic Measurement System, Fifth Edition, Prentice hall, New Delhi.

Rhys, L. (1983): Electronic Servicing Part II, Core Studies, Salisbury Whitshire, Hong Kong.

Ronald, J. T. (1999): Digital systems, Principles and Aplications, Seventh Edition, Prentice hall International Inc., New Delhi.

Robert, L. B. (1997): Electronic Devices and Circuit Theory, Prentice hall of India Private Limited, New Delhi.

Saha, T. N. (2001): Analysis of Asymmetrical Faults in Electrical Circuits, Fifth Edition, Hong Press, New Zealand.

Spark, I. (1999): Junction Transistors, Fifth Edition, Pergamon, London.

Tom, H. (1991): Communications and Electronics, Penguim Books, Madison Avenue, New York.

U. S. Institute for Highway Safety (1998-2003): Q and A on Red-light Camera Public Technology/Lockhead-Martin IMS Photo Enforcement Group, U.S.A.