

Remote Control via Can/Ethernet Gateway Using GPRS

James Agajo, Idigo V.E. and Isaac Avazi

Abstract—The work discussed, analyzed and evolved a solution to the problem relating to control and monitoring via a Controller Area Network (CAN) and ETHERNET interface. In this project the two technologies CONTROLLER AREA NETWORK (CAN) and ETHERNET were interfaced by configuring the HyperTerminal to transmit between the ports of the networks. Analysis on preference for CAN in message transmission over other existing options on the basis of immunity from noise and electromagnetic wave interference was also carried out using Fourier Series. Also covered was a Protocol that establishes a relationship between BUS LENGTH, DATA RATE and number of NODES in CAN BUS network. A model was generated for GPRS, which establishes a relationship between data rate and time. A Fourier series equation was also evolved for the Data fed into the nodes via the CAN BUS. Simulation using MATLAB Software of the Fourier series equation was generated, which gives a graphical representation of the signal transmitted, and the effect of noise. A software called Packet Tracer was used for the simulation of Packet movement. Proteus Laboratory a highly versatile Software was used in bringing up an animated Model for realising the simulation of the entire systems.

Index Terms— *Arbitrary, CSMA, Control unit, CAN, GPRS, Ethernet, sensors and actuators*

I. INTRODUCTION

The increasing complexity of control systems and especially the development of distributed control [1] demand communication systems suitable for their needs. CAN (Controller Area Network) - Bus (electrical channel for transferring data between computers) means a way of communication between Control Units in the vehicle. In order to understand the meanings and the purposes of this kind of communication, one must first understand the scope of electronic development in the automotive area and in particular in the modern vehicles. In the past, vehicles were simply constructed, that were outstanding in their reability. Each system of the vehicle was a stand-alone system constructed of mechanical and electro-mechanical components (some times combined with pneumatics). Due to those simple systems the

vehicle reactions to road or load changes was slow and not accurate, causing poor driveability, high fuel consumption and high air pollution.[1]

Today one expect that the vehicle will offer maximum driveability, high road safety, environmental friendliness and economy with the adoption of (CAN), Controller Area Network is a serial bus network of microcontrollers that connects devices, sensors and actuators in a system or sub-system for real-time control applications. This work extends the use of CAN towards realizing remote control and monitoring via CAN/ETHERNET interface using GPRS as illustrated in figure 1. There is no addressing scheme used in controller area networks, as in the sense of conventional addressing in networks (such as Ethernet). Rather, messages are broadcast to all the nodes in the network using an identifier unique to the network. On the other hand, Internet applications are becoming very popular in a fast and continuous way, under Ethernet applications, and due to the GPRS protocol, mobility in communications is a reality [2,3]. The third point which is one's duty nowadays refers to the new technologies, understood as a social revolution which is being incorporated in daily life quickly. These three technological supports have been joined in order to implement a system using field buses and interconnected to users through the GSM telephony network, using the GPRS protocol, and via Ethernet for non-mobile applications. This work, is focused on an industrial frame system, being easily expandable to other fields of application, such as industry, security, automotive, sailing, and so on. The system features will be the following ones as **Expandable, Open, Remotely controlled and With a model** :[4]

II. METHODOLOGY

Softwares like MATLAB, PROTEUS LABORATORY and VB EXPRESS EDITION were use in this work, PACKET TRACER from CISCO was equally used in configuring router., A flowchart for selection model is shown in figure 5.01. Fourier series transform an infinite trigonometric series of terms consisting of constants multiplied by sines or cosines, used in the approximation of periodic functions was used in evolving the waveform for each node on the CAN Bus.[5]

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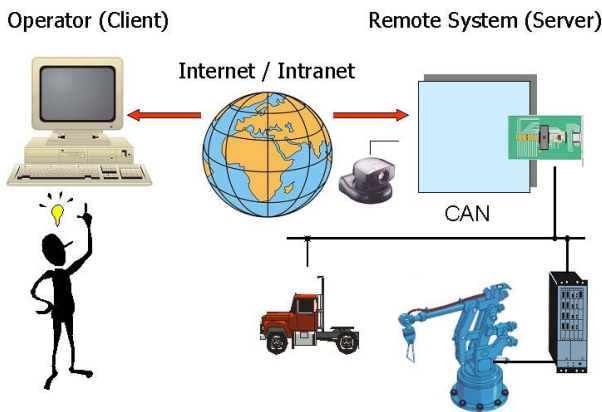


Figure 2.0 System structure for CAN/ETHERNET INTERFACE

III. CHOICE OF DESIGN APPROACH

Fourier Series, statistical models ,method of arbitration using CSMA were used. Fourier Series, was used to generate sine wave of transmitted signal in the nodes, The signal with the coupled noise arising from the equipment were analysed.

$$F(t)dt = \begin{cases} 1, & 0 < t < 1 \\ 0, & 1 < t < 2 \end{cases} \dots 3.1$$

A Fourier series a sequence of equation that follows the pattern

The Fourier transform gives the signal coupled with the noise which estimatebly represent signal to noise ratio.

$$(F_{r.m.s})^2 = (a_0)^2 + \frac{1}{2} \sum (a_n)^2 + (b_n)^2 \dots 3.2$$

An analysis of signal ratio to noise was carried out from the waveform, issues on when and how can the signal be noticed can be seen from the order of the Fourier series transform.

Error value from the signal generated in the CAN BUS was also calculated which is given as Root Mean Square of error value is given as

$$Fr.m.s = \text{Root Mean Square of error value}$$

1) Power dissipated due to noise effect is given as

$$F(t) = a_0 + \sum A_n \cos w_0 t + B_n \sin w_0 t \dots 3.3$$

2) $N = P = R F_{r.m.s} \dots 3.4$

R= RESISTANCE, F= ERROR VALUE

Response that depend on two or more response is called multiple regression

Data transfer rate obtained from GPRS with respect to time in kilobyte per second were used to evolve a model for effective speed control.

$$r = a + bt \dots 3.5$$

r = rate of data transmission

t = time of the day

This is achieved by measuring error range of different values.

A Protocol was also established in the CAN BUS network to bring up a relationship between CAN BUS length , Signal

length and number of Nodes,

$$L = F + GS + HP \dots 3.6$$

L = Distance between node in metres

S = signal rate kbps

P = Number of nodes per interval

H and G are constants

This involves multiple regression method involves 3 variables

IV. SYSTEM DESIGN

A. Arbitration

Arbitration is the mechanism that handles bus access conflicts. Whenever the CAN bus is free, any unit can start to transmit a message(CSMA), table 1 illustrate this. Possible conflicts, due to more than one unit starting to transmit simultaneously, are resolved by bit-wise arbitration using the identifier of each unit[6,7]

TABLE 1 TRUTH TABLES FOR DOMINANT /RECESSIVE AND LOGICAL AND

BUS STATE WITH TWO NODES TRANSMITTING

	dominant	recessive
dominant	dominant	dominant
recessive	dominant	recessive

LOGICAL AND

	0	1
0	0	0
1	0	1

A fundamental CAN characteristic shown in Figure 2 is the opposite logic state between the bus, and the driver input and receiver output. Normally a logic high is associated with a one, and a logic low is associated with a zero—but not so on a CAN bus. This is why it is desirable to have the driver input and receiver output pins of a CAN transceiver passively pulled high internally as shown in figure 4.1.[8,9]

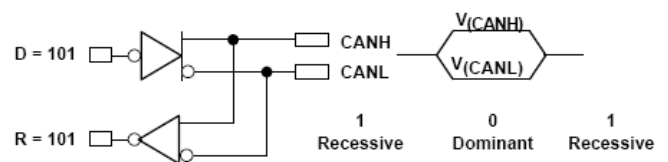


Figure 4.1 The Inverted Logic of a CAN Bus

B. Linear Regression

Linear regression method was used, that is least square regression analysis , for a given value of time t and data rate r

there will be difference between r_i and the corresponding value as determined from the line in figure 4.2, and as indicated the figure denotes the difference which is referred to a deviation, error or residual and may be positive or negative or zero

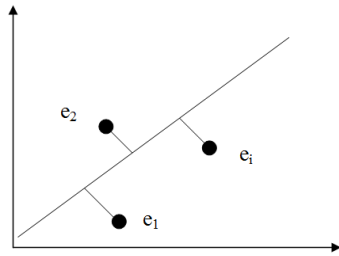


Figure 4.2 Data Point Error range

e represent Error range from the actual supposed expected value.

e =error

Let r = Data rate

t =time of the day

$e_i = r_i - r$

$$e_i^2 = \sum_{i=1}^n (r_i - r)^2 \dots\dots\dots 4.1$$

$$\sum_{i=1}^n e_i^2 = (r_1 - r)^2 + (r_2 - r)^2 + \dots\dots\dots + (r_n - r)^2 \dots\dots\dots 4.2$$

let ϕ = sum of square of errors = ϕ

$$\begin{aligned} \phi &= \sum_{i=1}^n (r - (at + b))^2 \\ &= \sum_{i=1}^n (r_i - at - b)^2 \end{aligned} \dots\dots\dots 4.3$$

error is minimise when we differentiate equation 4.3 with respect to a & b .

$$\sum_{i=1}^n dr + a \sum_{i=1}^n t_i^2 + b \sum_{i=1}^n t_i = 0$$

$$\frac{d\phi}{da} = 2 \sum_{i=1}^n (r - at - b)(-a) = 0$$

$$\frac{d\phi}{db} = 2 \sum_{i=1}^n (r - at - b)(-1) = 0$$

$$\sum_{i=1}^n r = a \sum_{i=1}^n t + \sum_{i=1}^n b \dots\dots\dots 4.4$$

$$\sum_{i=1}^n dr = a \sum_{i=1}^n t^2 + b \sum_{i=1}^n t \dots\dots\dots 4.5$$

Combining equation 4.4 & 4.5

$$\begin{aligned} a &= \frac{(\sum r)(\sum t^2) - (\sum t)(\sum tr)}{n\sum t^2 - (\sum t)^2} \\ b &= \frac{n\sum tr - (\sum t)(\sum r)}{n\sum t^2 - (\sum t)^2} \end{aligned}$$

$$r = a + bt \dots\dots\dots(4.6)$$

Mathematical model representing data rate Transmission
 Model $r = a + bt$

C. PROTOCOL

A Protocol was also established in the CAN BUS network to bring up a relationship between CAN BUS length, Signal length and number of Nodes,

$$L = F + GS + HP \dots\dots\dots(4.7)$$

D. Noise Immunity

Fourier Series transform

Noise level as a result the device connected to the network is calculated using Fourier series, here figure 5.3,5.4 and 5.5 coupled with signal in node 1,2 and 3, the resulting signal is shown in figure 5.6,5.7 and 5.8.

One may wish to analyse signal from a node in the CAN bus, if 4 the signal is govern by the sequence as represented by the function of t and $f(t)$ below

$$F(t)dt = \begin{cases} 1 & , 0 < t < 1 \end{cases} \dots\dots\dots 4.8$$

The equation generated becomes

$$\begin{aligned} y &= 0.5 + 0.6366 * \sin(x) + 0.2122 * \sin(3 * x) + 0.1273 * \sin(5 * x) \\ &+ 0.0909 * \sin(7 * x) + 0.0707 * \sin(9 * x) + 0.0579 * \sin(11 * x) \\ &+ 0.04897 * \sin(13 * x) + 0.04244 * \sin(15 * x) + 0.0374 * \sin(17 * x) \\ &+ 0.03351 * \sin(19 * x) + 0.03032 * \sin(21 * x) + 0.02768 * \sin(23 * x) \\ &+ 0.0255 * \sin(25 * x) \end{aligned}$$

to check CAN immunity to noise the r.m.s error value is calculated as

$$\begin{aligned} F_{r.m.s}^2 &= a_0^2 + 1/2 \sum a_n^2 + b_n^2 \dots\dots\dots 4.9 \\ a_n^2 &= 0 \\ &= 0.5^2 + 0.124 \end{aligned}$$

Power dissipated due to noise effect

Fr.m.s = 0.7043

$N = P = R \text{Fr.m.s}$ 4.10

Signal = 1

Noise = $N = 1 - F_{r.m.s}^2$

$N = 1 - 0.7043 = 0.2957$

$S/N = 1/0.2957 = 3.382$

Here signal value 3.382 indicate high integrity

The data transfer rates were calculated using the formula to get the transfer rate in kilobits per second.[10,11]

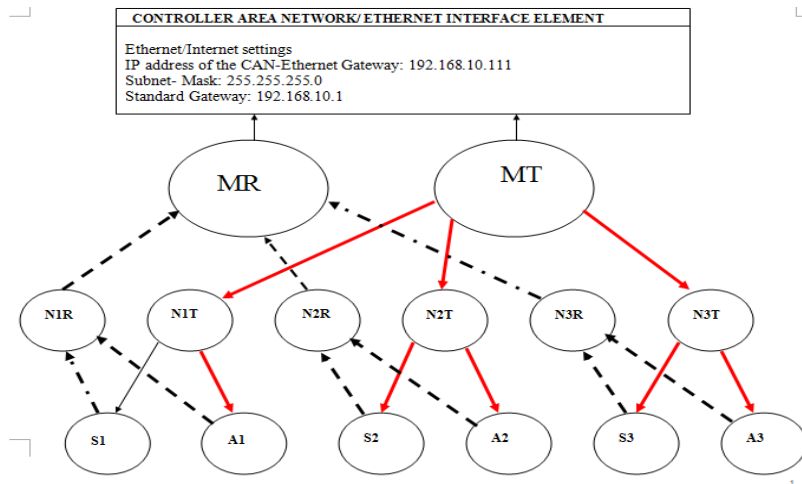


Figure 4.3 Can /Ethernet Flow Chain

V.SYSTEM IMPLEMENTATION (HARDWARE SUBSYSTEM IMPLEMENTATION)

The principle possibilities for building a network structure using CAN- Ethernet Gateways are represented as seen figure 4.3

MR : Master element at receiving mode to receive signal from sub-control units

MT: Master element at transmitting mode to transmit signal to subsystem

N1R: Node one in receiving mode to receive from a unit of subsystem

N1T: Node one in transmitting mode to transmit to a unit of subsystem

N2R: Node two in receiving mode to receive from a unit of subsystem

N2T: Node two in transmitting mode to transmit to a unit of subsystem.

$$\left(\frac{1081623 \text{ bytes}}{\text{The transfertime in seconds}} * 8 \right) / 1000$$

...4.11

A. Initial Configuration using the RS-232 Interface

The CAN-Ethernet Gateway was configured to meet to meet the specific

In table 2, this application is requirements before CAN messages can be transmitted.

TABLE 2 INTERFACE FOR SIGNAL CONVERSION BETWEEN CAN AND ETHERNET

LED Name	Description
power	Supply Voltage OK [green]
connect	A connection to the other Gateway is established over BTP or TCP [green]
error (Ethernet)	Error during data transfer on the Ethernet connection
link	Connection to Ethernet established, cabling OK [green]
active	Data transfer over Ethernet [yellow]
traffic	Indicates data traffic on the CAN bus [green]
error (CAN)	Error during data transfer on the CAN connection

The following steps are required:

Connect the included null modem cable to the RS-232 interface of the CAN-Ethernet Gateway and a free serial interface on the PC (e.g. COM1).[13,14]

Invoke a terminal program on the PC, the program "HyperTerminal" will be used for the following examples, this program is part of the MS-Windows operating system (if you use a different terminal program, appropriate configuration must be made).

Baud rate will be set and the protocol for the serial interface (e.g. COM1) in HyperTerminal.

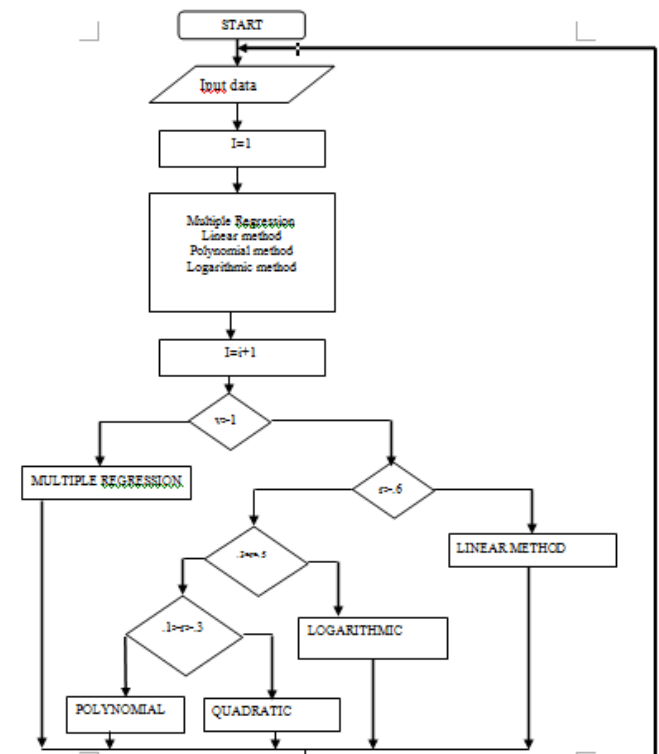


Figure 5.01 Flowchart of Model

B. Connecting to a CAN Bus

A DB-9 plug is provided for connection of the device to a CAN network. Alternatively a connection via the 5-pin removable screw clamp connector is also possible (suitable connector PHOENIX CONTACT 1757048). This connector

is wired parallel to the DB-9 plug. Its configuration corresponds to the DeviceNet and CANopen standard.[11]

The supply voltage for the CAN bus (pin 9 at DB-9 or pin 5 at 5-pin socket connector) is not connected in the Gateway. The CAN shield potential is only connected between the two CAN connectors. The CAN bus is galvanically separated (optically isolated) from the Gateway's internal circuitry.[12]

C. Serial Communication Property

- RS-232 interface
- Baud rate: 9600 baud
- Data bits: 8
- Parity: none
- Stop bits: 1
- Protocol/flow control: hardware
- RS-232 interface
- Baud rate: 9600 baud
- Data bits: 8
- Parity: none
- Stop bits: 1
- Protocol/flowcontrol:hardwar

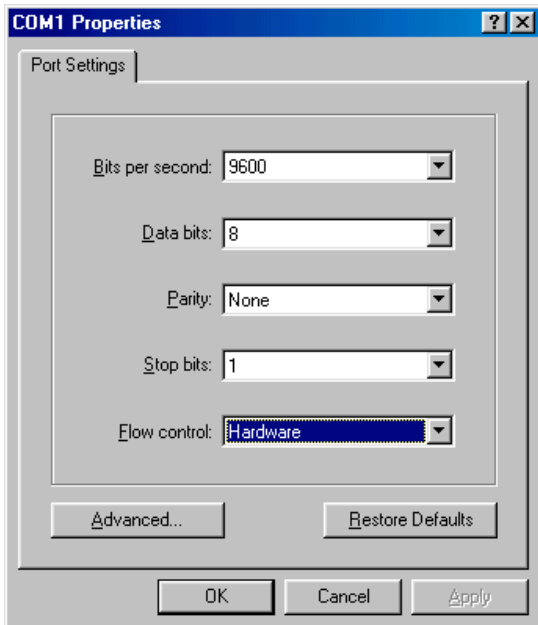


Figure 5.1: HyperTerminal Configuration (1)

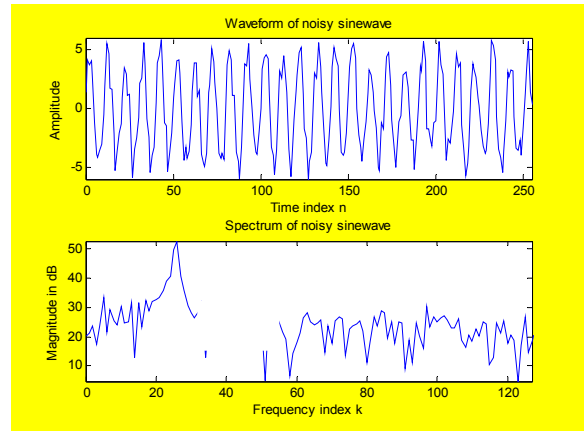


Figure 5.5 Actual signal has coupled with noise in node2

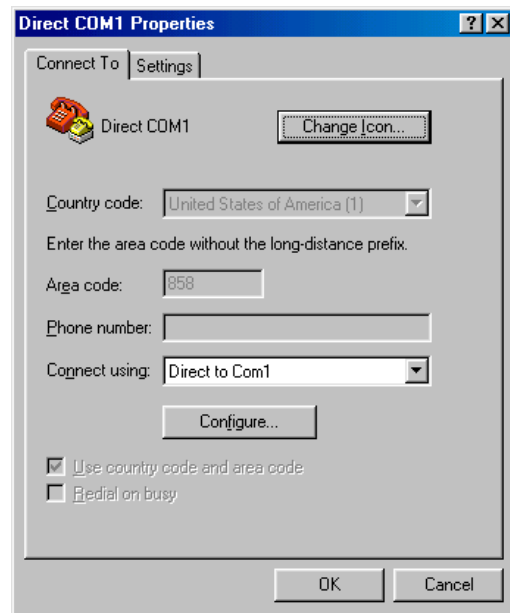


Figure 5.2 : HyperTerminal Configuration (2)

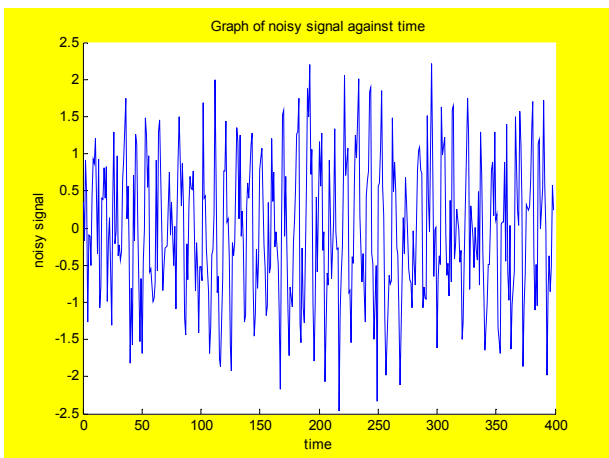


Figure 5.3 Graph showing noisy signal couple to signals in node 1

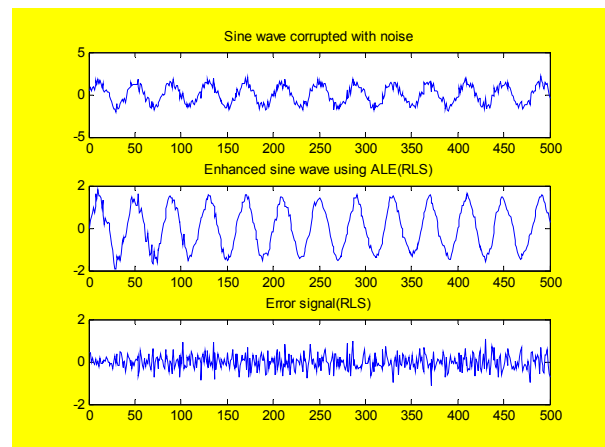


Figure 5.4 Actual signal has coupled with noise in node2

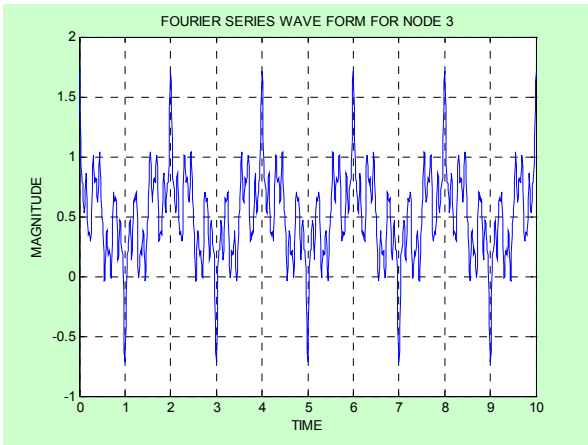


Figure 5.6 Graph showing noisy signal couple to signals in node 2

confirming the high noise immunity of CAN given rise to signal in figure 5.6,5.7 and figure 5.8.

Connect the included null modem cable to the RS-232 interface of the CAN-Ethernet Gateway and a free serial interface on the PC (e.g. COM1).[13,14]

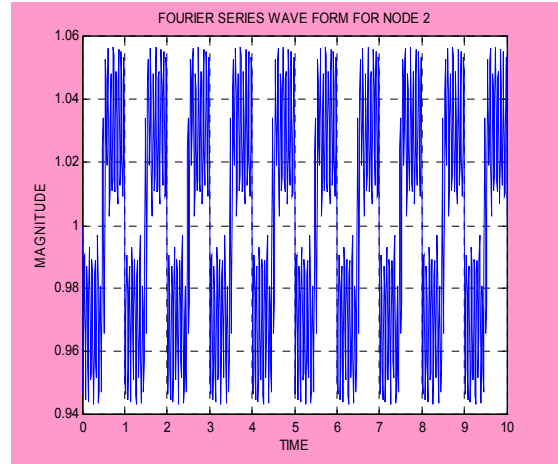


Figure 5.8 Actual signal has coupled with noise in node 3

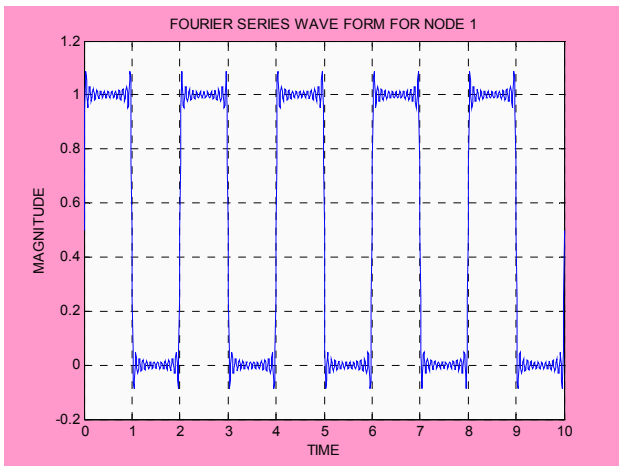


Figure 5.7 Actual signal has coupled with noise in node 3

Invoke a terminal program on the PC, the program "HyperTerminal" will be used for the following examples, this program is part of the MS-Windows operating system (if you use a different terminal program, appropriate configuration must be made).

$$a = 50.27, b = -2.1900$$

$$r = a + bt$$

$$b = \frac{n \sum tr - (\sum t)(\sum r)}{n \sum t^2 - (\sum t)^2}$$

FOURIER SERIES is used to generate the equation for the waveform, the different digital signal sent to nodes as shown in figure 4.6 in chapter four is shown using MATLAB different noise levels where coupled with the signals thereby

TABLE 5.6 RESULTS OF DOWNLOADING THE DATA

SN	BUS LENGTH	SIGNAL RATE Kbps	NUMBER OF NODES
1.	30	1000	22.3
2.	43	920	33.78
3.	59	800	44.23
4.	80	730	60
5.	100	500	75
6.	120	400	90
7.	160	380	120
8.	180	300	135
9.	210	280	157.5
10.	230	230	187.5
11.	300	200	225
12.	320	300	240
13.	400	400	300
14.	430	130	337.5
15.	500	123	375.3
16.	550	123	412.5
17.	590	110	450
18.	600	113	487.5
19.	650	300	502.5
20.	750	311	600
21.	800	110	607
22.	810	90	637
23.	850	83	687.5
24.	890	73	675
25.	900	70	712.5
26.	950	100	713
27.	1000	62.5	750

Fourteen downloading tests were performed during different times of the day between 9.30 a.m. and 16.00 p.m.

on the 10th of Jan 2003. The test results are in the following table.

$$\begin{aligned} \sum t &= 178.5 \\ \sum r &= 307.64 \\ \sum t^2 &= 2032.25, \quad \sum tr = 4069.325, \quad \sum r^2 = 7082.88 \\ a &= \frac{(\sum r)(\sum t^2) - (\sum t)(\sum tr)}{n\sum t^2 - (\sum t)^2} \end{aligned}$$

$$r = 39.93924 - 1.64137t \dots\dots\dots 4.24$$

VI. PROTOCOL

A. The Relationship Between Bus Length and Signaling Rate Number of nodes

A protocol that establishes a The Relationship Between Bus Length and Signaling Rate Number of nodes was evolved with the The general purpose of multiple regression which is to learn more about the relationship between several independent variables. For example **Table 5.3**

B. Downloading Data Transfer Rate

Fourteen downloading tests were performed during different times 5.11 Computational Approach

The general computational problem that needs to be solved in multiple regression analysis is to fit a straight line to a number of points the points will be used to establish the protocol.

L = Distance between node in metres

S = signal rate kbps

P = Number of nodes per interval

MATLAB was used in solving F,G and H

F=541.1521

G= -0.5259

H = 0.06556

The protocol stand as

$$L = 541.1521 - 0.5259S + 0.06556P$$

This protocol governs the relationship between BUS LENGTH, NUMBER OF NODES AND SIGNAL RATE.

$$r = a + bt$$

TABLE 2 RESULTS OF DOWNLOADING THE DATA

N	Time(t)	Data Rate(r)	d ²	ds	t ²
1	9.5	30.59	90.25	290.605	935.748
2	10.0	26.39	100	260.39	696.432
3	10.5	24.30	110.25	255.15	590.49
4	11.0	20.0	121	220	400.00
5	11.5	18.0	132.25	207	324
6	12.0	14.0	144	168	196
7	12.5	14.0	156.25	175	196
8	13.0	14.36	169	186.68	206.210
9	13.5	18.0	182.25	243	324
10	14.0	20.0	196	280	400
11	14.5	25.0	210.25	365.5	625
12	15.0	27.0	225	405	729
13	15.5	26.0	240.25	403	676
16	16.0	28.0	256	448	784
	$\sum t=178.5$	$\sum r=307.64$	$\sum t^2=2032.25$	$\sum tr=4069.325$	$\sum r^2=7082.88$

TABLE 5.1 MAXI MUM SIGNALING RATES FOR CABLE LENGTHS

$$\begin{aligned} \sum SP &= 1925000 \\ \sum SL &= 6394100 \\ \sum PL &= 187424 \\ \sum S^2 &= 78755967 \\ \sum P^2 &= 4426300 \end{aligned}$$

From equations chapter four

$$\begin{aligned} \sum L &= NF + G\sum S + H\sum P \\ \sum SP &= F\sum S + G\sum S^2 + H\sum SP \\ \sum PL &= F\sum P + G\sum SP + H\sum P^2 \\ L &= F + GS + HP \end{aligned}$$

C. ANIMATED MODEL

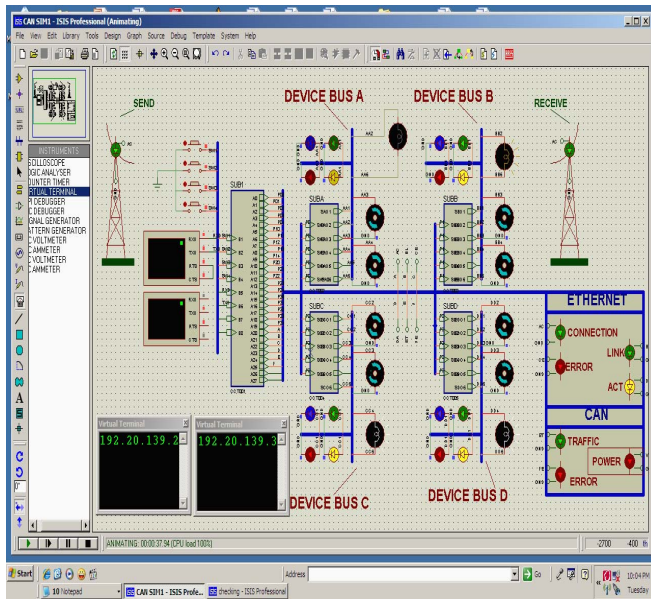


Figure 5.9 Animated module of an ABS CONTROL system

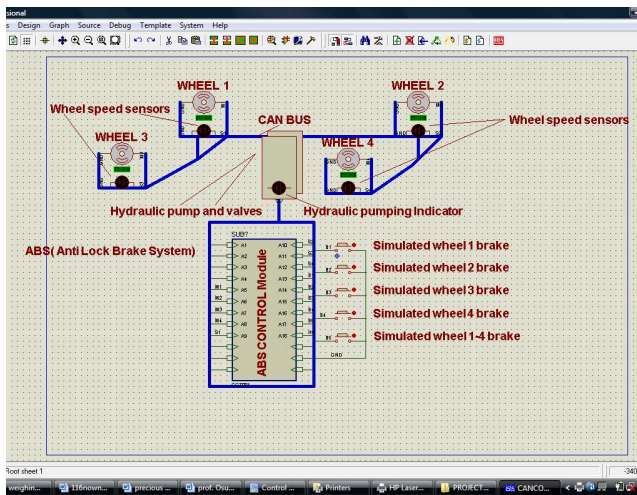


Figure 5.10 Animated module of an ABS CONTROL system

A master element which can be identified and seen as the central element in the diagram directs and control all other sub-units. The terminal represent the computer on the Ethernet side which is used as default for receiving and sending codes.

D. Animated Model

The models in figure 5.8 , figure 5.9 are virtual representation of the work , figure 5.14 is a model of ABS Control system with four wheel and sensors ,in figure 5.15 four CAN BUSES were networked by linking to the super highway known as the BUS.

Signal are received and transmitted via the antenna , an indicator is made available for status monitoring between both CAN and Ethernet network.

VII. CONCLUSION

This work successfully achieved the simulation of the model for The work on CAN/ETHERNET GATEWAY, it also confirm that remote control can be achieved via CAN/ETHERNET INTERFACE.

This thesis was able to establish a gateway between a CAN and another communication network like Ethernet and so on.

Work on different types of CAN gateways, e.g., CAN-RS232 and CAN-TCP/IP gateways was analysed. It showed that the latter can provide remote access to a CAN through the Internet, which allows worldwide monitoring and maintenance. The real-time capability were also seen from the animated model with PROTEUS LABORATORY , the role played by CSMA/CA in message transmission and collision avoidance was also observed.

One major contribution was the establishment of a Protocol which governs the relationship between **Signaling Rates, Cable Lengths and number of nodes**, which will give approximate value for the interdependent variables

A GPRS MODEL was established which shows the trend in data rate with respect to particular time of the day

That a personal computer can also be used as a CAN-Ethernet Gateway was also achieved, whereby the local CAN hardware (PC-CAN interface) was used as a gateway to a CAN network. The PC functions as a gateway to the Ethernet. CAN-based control systems should be used in factory and building automation and embedded control systems for machines, medical devices, domestic appliances and many other applications.

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