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DEVELOPMENT OF A MICROCONTROLLER BASED DIGITAL TELEPHONE TRAFFIC CONTROL USED FOR RADIO AND TELEVISION STUDIO PHONE-IN PRODUCTION

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Abstract*— In radio and television business, adequate dissemination of valuable information to the target audience is the primary goal. Phone in programs gained wide acceptance in the last two decades and more especially, with the growing passion for reality radio. The developed microcontroller call traffic control system controls incoming telephone traffic during a phone in program. It also facilitates the function of an intercom system between the presenter and the program director. The model allows two to three professionals discuss important issues relevant to the society and outside contributions from the audience (viewers or listeners) through their telephone lines. The system is made up of two receiver sets and a device that samples calls and sends one call at a time to the presenter. The system knows when the contributor is through with his contributions, so that another call that is on hold is released to the presenter. The valuable contribution to society from this work is that it can control the indiscriminate flow of call traffic from contributors outside the studio during the phone-in production.

***Keywords*— Microcontroller, Voltage level controller, Voltage level detector, Intercom system, Measurement, and Reliability.**

1 INTRODUCTION

Typical radio stations have at least two separate audio studios,on-air studio **and** production studio**[13][4]**. The on-air studio is "live" and sends programming to the transmitter. The production studio is used for producing recorded programming for future on-air use. It is also possible to utilize one studio for both functions in a situation where space constraint prevents the installation of two separate studios. The key to achieving this dual function is a console with two separate outputs. Each input channel to the console is selected to feed either the **"**program" output for on-air immediate broadcast, or the "audition" output to the recording equipment for future broadcast. In this manner, a program may be recorded in audition, while at the same time the station is "on-the-air" in program**[13]**.This setup allows the guest and the presenter to be in the studio, where two live microphones are dedicated to them. These microphones could be a neck or a standing type, whose output goes directly to the console for the transmission director to control[6]. Another live microphone line is dedicated to the output for callers, but only if the console lacks the hybrid of Phone Interconnections Systems. These devices are used to connect phone systems to the console allowing the caller to hear the broadcast during the production[3]. Incoming calls are intercepted through the stations telephone line that has a means of identifying a call, but on mute to prevent feedback**[13].** The station may have as many as four known and dedicated telephone line numbers, through which contributors can call to ask questions or contribute to a discussion[6]. In the traditional matrix technique, the routing of audio and video systems depend on the size of the input and output ("ports") in relation to the matrix in the mathematical square law relationship [16]. The telephone recording application acts as an answering machine and records the two-way calls. All data for the call is stored in the data base, including meta data and the audio file itself (as windows Media Audio - WMA). To play the audio, it is copied out of the data base to a temporary file and played.Figure 1 represents the schematic diagram of a broadcast studio setup that consists of the following seven components:

1. **Microphone**: The broadcast studio typically has at least two powerful microphones – one for the host or presenter and the other for the guest.
2. **CD players**: The CD players are for play back, especially, for music. Two CD players may be very useful in broadcast studio allowing pre-recorded materials to be smoothly mixed.
3. **Mixer:** The mixer is the heart of the studio that facilitates the combination of a verity of inputs and manages the audio levels of the various sources and microphones. The main functions of a mixer are handled by equalizer controls (which allow the tone and quality of the audio be controlled); pan controls which allow mixing in stereo; and gain controls which allow the boosting of inputs.
4. **Head phones and Monitors:** The head phones are used to monitor the audio going on air and to preview a new source before its sound is actually mixed in. The studio use speakers and a switch system that allows the on air audio be heard over the monitor speakers.
5. **Distribution Amplifier:** This allows the feeding of the main output to the recording units (this may not be necessary if the entire process is oriented around a computerized editing system) and to the broadcast studio.
6. **Pre-amplifier and amplifier units:** Several source units within the setup may have very low signal outputs which needed to be amplified by pre-amplifier unit. The output leaving the mixer is boosted by the amplifier unit before the final transmission at the transmitter end. This part of the signal is also used for monitoring purposes through headphones and speakers as illustrated in Figure 1.
7. **Telephone hybrid unit:** One of the best ways to involve the listeners or viewers in the programme is to give them an opportunity to call in during the production, so that they can also participate fully. To get the callers on air,a telephone hybrid unit is required. Intercom is also a similar system but in this case it has fixed phones connected by guided media [11]. Another system that functions differently but related is the VOIP intercom system whichsupports the communication between indoor machines, outdoor machines and management center machines, but the call of management center machines has the highest priority[17].The hybrid unit connects the telephone line to the mixer unit. The number of lines dedicated to callers are made known to them **[13][15]**. The problems to be solved by this paper are two-fold:First, to facilitate simultaneous calls during call-in radio programmes and second, control the inflow of calls from contributors outside the studio during the phone-in production to avoid interference. To achieve these contributions requires the design and development of an accurate and efficient telephone traffic control system.

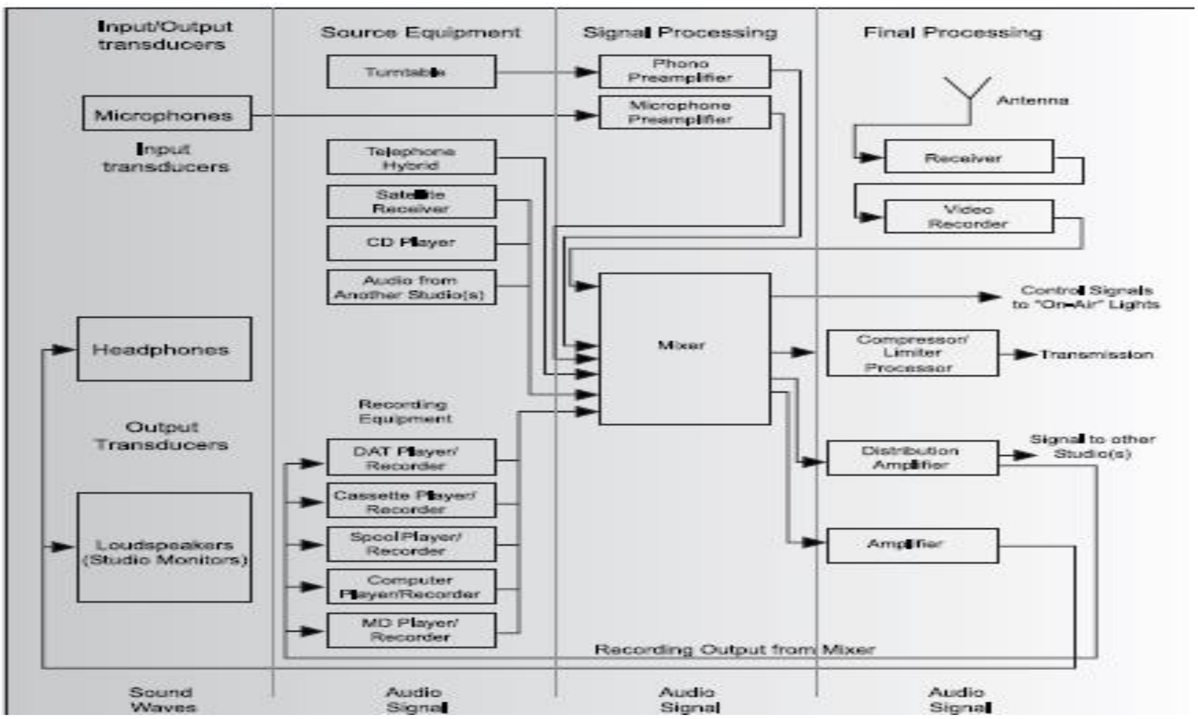

Figure1: Schematic Diagram of a Broadcast Studio Setup**[14]**

II. MATERIALS AND METHODS

This work is intended to control the indiscriminate flow of calls from contributors outside the studio during phone-in production and is achieved using microcontroller PIC 16F84A, seven segment display, CMOS IC4069, audio amplifier IC TDA 2822, relay switches, discrete components like transistors, resistors and capacitors The method adopted starts by first designing the different modules of the system and then integrating them into a simple system.

1. Designing and analyzing of the main control and the intercom unit
2. Designing of the system's development procedure flowchart of the process followed.
3. Measurementsof all relevant parameter values in conformity with specifications.
4. Reliability evaluation of the system.

2.1 DESIGN AND ANALYSIS OF MAIN CONTROL AND INTERCOM UNIT

The voltage level control is designed and implemented using the circuit diagram of Figure2. The voltage level controls serve as reference voltages to the microcontroller. They are used by the microcontroller in ascertaining the precedence of incoming calls. When R_{V1} is set to 10V, it is considered normal voltage control,that is, when none of the lines in Figure 2 is active[1].

2.1.1 Design and Analysis of Main Control

Figure 2 is the voltage level control unit design layout. When line 1 is active, 11V is set atR_{V2}, a signal that is sent from the microcontroller to the intercom is detected by the detector, and it is an indication that line 1 is high. The same is applied to line 2. With a voltage of 12V set atR_{V3}, a signal sent from the microcontroller to the intercom is detected, and it is also an indication that line 2 is high. Both lines can be active at the same time, which implies that two calls can come at the same time on the line marked "line 1 + line 2" representingthe 13V line. When the microcontroller sends the two signals at the same time which implies high and high, the circuit behaves like an AND gate, the high signal is amplified by the LM339, and $R_{V4}$is set to 13V[8]. The detector in the intercom detects the 13V signal and is an indication that the two lines are high. It is now left to the presenter to select which of the two calls to answer first.

From Figure2,

$$R_{V_1} = R_1 + R_2 \quad (1)$$

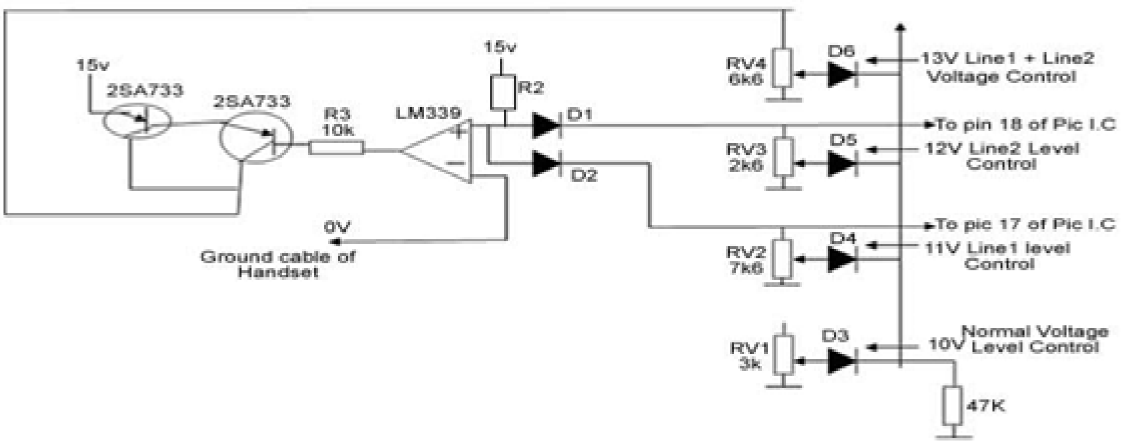

Figure 2: Voltage Level Control Unit

From Figure 2, the reference voltage V_1 for normal control voltage level is set to 10V,$V_2$to 15V, and the op-amp LM339 and the Darlington pair that behaves like a single transistor with a very high current gain are also considered[14]. Since the transistors used are to operate as switches, the cut-off and saturation characteristics of the transistors are of concern to this work. Saturation collector – emitter voltage V_{CE} (sat) ~ 0.2 V and that of the base –emitter voltage V_{BE} (sat) ~ 0.7V. At cut off, V_{CE}~ V_{CC} because the base current equals zero[12].

In this design,R_{v4} is set to 2kΩ out of the calculated 15kΩ for the 13V voltage level control[8]

From data book [12]:

$R_{v4}$is served as the load resistor of the transistorQ_2 = BD 132

R_L= 2kΩ

h_{fe}(min) = 40 from [12]

I_C(max) = 3A

At cut-off:

$I_C \;\; = I_{CO} \sim 50\text{nA}$

$V_{CE} = \; V_{CC} - I_{CO} \times R_C$ (2)

$V_{CE} = 11.999 \sim 12\text{V}$

Since the op-amp is operating in open loop at unity gain, the base voltage of Q_1 is equal to the output voltage of the op-amp[9].

$V_{B1} = V_O \sim 12\text{V}$

$V_{BE1} = V_{CC} - V_{BE2}$ (3)

$$R_b \; = \frac{(V_{CC} - V_{BE})}{I_B}$$

$V_{BE2} = 13\text{V}$

$$R_b \;\; = \frac{(V_{B1} - V_{BE1})}{I_{B1}}$$

Substituting for V_{EE1} from equation (3), equation (4) becomes:

$$R_b \;\; = \frac{\left(V_{B1} - (V_{CC} - V_{BE2})\right)}{I_{B1}}$$

$= 9.59k\Omega \sim 10\text{k}\Omega$

Value used of R_b equals to 10kΩ

R_3 in Figure 2 is the base resistor of Q_1, 2SA733

Table 1 contains the values calculated and those actually used in the design for the voltage level control components.

Table1: Voltage Level Control Components

Component	Calculated value	Used value
R_{V_1}	3kΩ	3kΩ
R_{V_2}	7kΩ	7kΩ
R_{V_3}	2.5kΩ	2kΩ
R_{V_4}	15kΩ	15kΩ
R_3	9.59kΩ	10kΩ

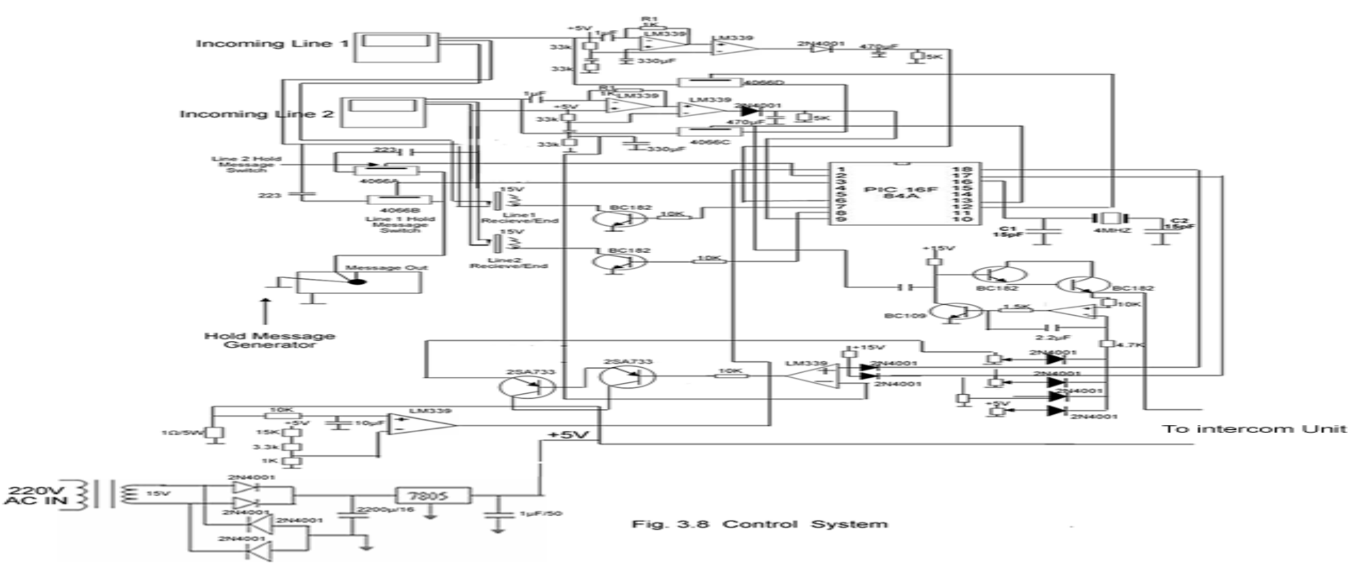

Figure 3 Main Control Units

2.1.2 Design and Analysis of the Intercom Unit

The intercom unit is designed and implemented based on the arrangement shown in Figure4. The intercom unit comprises of the voltage level detector and an audio amplifier. The unit facilitates communication between the presenter and the caller. The presenter accepts the incoming call via a switchattached to the intercom unit, thus establishing communication between himself and the caller.

2.1.2.1 Design and Analysis of Voltage Level Detector

The voltage level detector circuitry is composed of three comparators (LM339) used to detect the levelsgenerated from the main control unit. There is

detector circuitry in the intercom unit[7]. The positive inputs to the three comparators LM339 (1), (2), and (3) have V_{ref3} as input from the divider network [9]as shown in Figure 3.The reference voltages to the two comparators generating +11V and +12V are determined from a divider network of R_4, R_5, and R_6, while that of +13V is determined from the two networks(that is, from +11V added to potential across 4.7kΩ and 5.6kΩ networkbecause the circuitry at this point behaves like an AND gate). From the ground to end of R_4 resistor of the divider network, +11V is achieved as the reference voltage to the first comparator[8]. Therefore, with the low signal switched from the divider network of$R_7$and R_8, Q6 in turn switches line 1 indicator, signifying a also the receive/end pulse detector, which is used to alert the microcontroller that the presenter has picked or ended a call. Incorporated in the circuitry is a voltage divider network. The voltage at the point of the division serves as reference to the buffer. The two transistors arranged to form a Darlington pair are used to boost the output of the comparator. Any change in the current level automatically alerts the microcontroller that the presenter has received or ended a call. The two display counters are used to indicate which of the calls is received. The four voltage levels +10, +11, +12, and +13V that are

generated from the voltage level control circuitry of main control unit are detected through the level call from line 2. From the ground to the end of R_5 resistor, +12V is achieved as the reference voltage to the second comparator[8]. Also, with the low signal from the divider network of R_7 and R_8 switched, Q_3 in turn switches "ON" line 1 indicator, signifying a call from line 1. At this time, Q_2 switches off line1. From the ground to the end of R_7 of the second divider network, reference at R_7 from the ground plus 11V is achieved (behaves as AND), in this case, the input signal is much higher than the reference voltage, resulting in the switching on of both the indicators, signifying calls from the two lines. Considering the first voltage divider withR_4, R_5,andR_6, at the end of R_4 from the ground, the generated voltage is given by V_{ref1}**[8].**

Considering the potential divider with R_1 and R_2, $V_1$is set to detect 10V, that is, at normal condition, $V_{CC}$is 15V when receive end button is switched on.

$R_1 = \frac{V_1}{V_2 - V_1}$x R_2

From equation (5), R_2 = 5kΩ, the nearest value used is 5.6kΩ[12].

$V_{ref1}$is when the first line is active,that is, when the detection voltage is approaching 11V. Considering the potential divider generated byR_4, R_5 and R_6**[2][9]**.

$V_{ref1} = \frac{R_4}{R_4 + R_5 + R_6}$ x V_{CC}(6)

Let R_4 be 39kΩ in this design. In reality R_5 and R_6 can never be negative, but R_5 can be equal to R_6. Therefore in this design we setR_5= R_6=2.2kΩ.

Considering the potential divider generated by R_7andR_8, the reference voltage to be detected is 12V, thereforeV_{ref3} is given by

$V_{ref3} = \frac{R_7}{R_7 + R_8}$ x V_{CC}(7)

Let R_7 *be* 4.7KΩ for this design.

From equation (7), R_8 = 5.28KΩ and the nearest value in data book used is 5.6KΩ[13].

R_{b1}= 10kΩ as calculated from Figure 3.

$V_{ref1} = \frac{39K \text{x VCC}}{(39K + 2.2K + 2.8K)}$

V_{ref1} = 11V

$V_{ref1}$is considered as the reference voltage to the first comparator[8].

At the end of the R_5 resistor of the same divider network from the ground, the generated voltage is given by V_{ref2}

$V_{ref2} = \frac{(2.2K+39K)}{(2.2K+39K+2.8K)}$ x Vcc

= 12.08 ~12V

V_{ref2} = 12V

$V_{ref2}$is considered as the reference voltage to the second comparator[8].

(5) Let R_1 = 10kΩ

Considering the second divider network with $R_7$and R_8, at the end of the R_7 from the ground, the g enerated voltage is V_{ref}plus the already switched V_{ref1}

(The circuitry behalves like an AND gate at this point).

$V_{ref3} = \frac{4.7K}{(4.7K+5.6K)}$ x Vcc + V_{ref1}

V_{ref3} = 13.282v.

$V_{ref3} \sim 13V$

In this circuitry, the current limiting resistor to the seven-segment display is 10kΩ just as calculated in equation (4). For simple circuits where the comparator and the load share the same power supply (V_C=Vcc), the following expression can be used to calculate$R_{b2}$from Figure 3 **[2][9]**, that is:

$V_{b2} = 0.2\, x R_L x h_{fe}$ (8)

In all the three comparators 1, 2, and 3, the transistors used is BC182, and it has the following specifications [12]

I_C(max) = $100mA$,

h_{fe}(min) = 100.

From equation (8), R_{b2} = 0.2 × 100 × 1000 = 20,000Ω or 20kΩ, which is used as the base resistor for all the three comparators.

Table 2. Voltage Level Detector's Components

Components	Calculated values	Used values
R_1	10kΩ	10kΩ
R_2	5kΩ	5.6kΩ
R_{b1}	9.59kΩ	10kΩ
R_4	39kΩ	39kΩ
R_5	2.2kΩ	2.2kΩ
R_6	2.2kΩ	2.2kΩ
R_7	4.7kΩ	4.7kΩ
R_8	5.28kΩ	5.6kΩ
R_{b2}	20kΩ	20kΩ

The last op-amp, LM339(4) attached to the voltage level detector used as an inverting buffer is to serve as receive/end pulse detector[8].

Considering the voltage divider, the reference voltage V_{ref} is generated from Figure 3 as follows:

$$V_{ref} = \frac{R_2}{(R_2+R_3)} xVcc$$

V_{ref} = 5.38V

Therefore, negative output is expected at the output of the inverting buffer. When the switch is closed, the current flows and the input is expected to go higher than 5V dropping the output of the buffer to low because of its inverting nature. The first PNP transistor switches on with negative input why? and current flows through the 47Ω/5W resistor because the resistor is across the supply, the level of the current increases, this little change in current is acknowledged by the microcontroller, to know that the presenter had accepted or ended a call [2][9].

III. SYSTEM DEVELOPMENT AND IMPLEM ENTATION PROCESS FLOWCHART

Figure 5 is the flow chart of the complete system showing the sequence of implementation of the device.

3.1 MEASUREMENTS OF PAMETER VALUES

Measurement of Power Consumption of the Intercom Unit:

The power consumed by the intercom unit when it is in operation is measured in the setup arrangement as shown in Figure 6.

When any of the incoming lines is accepted by the presenter by pressing the accept/end bottom, current flows from the DC source to the intercom unit and the value of the consumed current and voltage are determined from the reading of the multi-meter shown in Figure 6. The voltage and current consumed by the intercom unit from the power source are tabulated in Table 3.

The average power consumed by the intercom unit is given by:

$P_{ave} = V_{ave}$ x I_{ave} (9)

= 54.59mA x 15.56

= 0.849watts

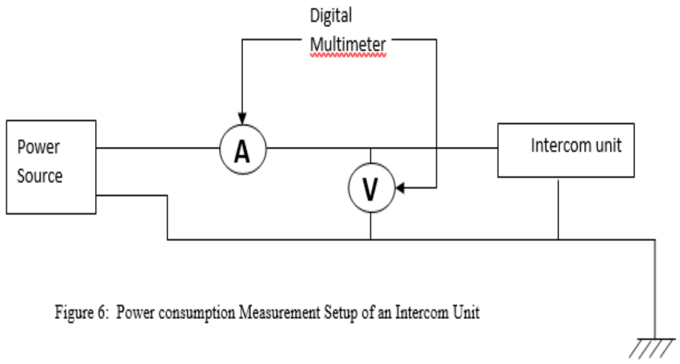

Figure 6: Power consumption Measurement Setup of an Intercom Unit

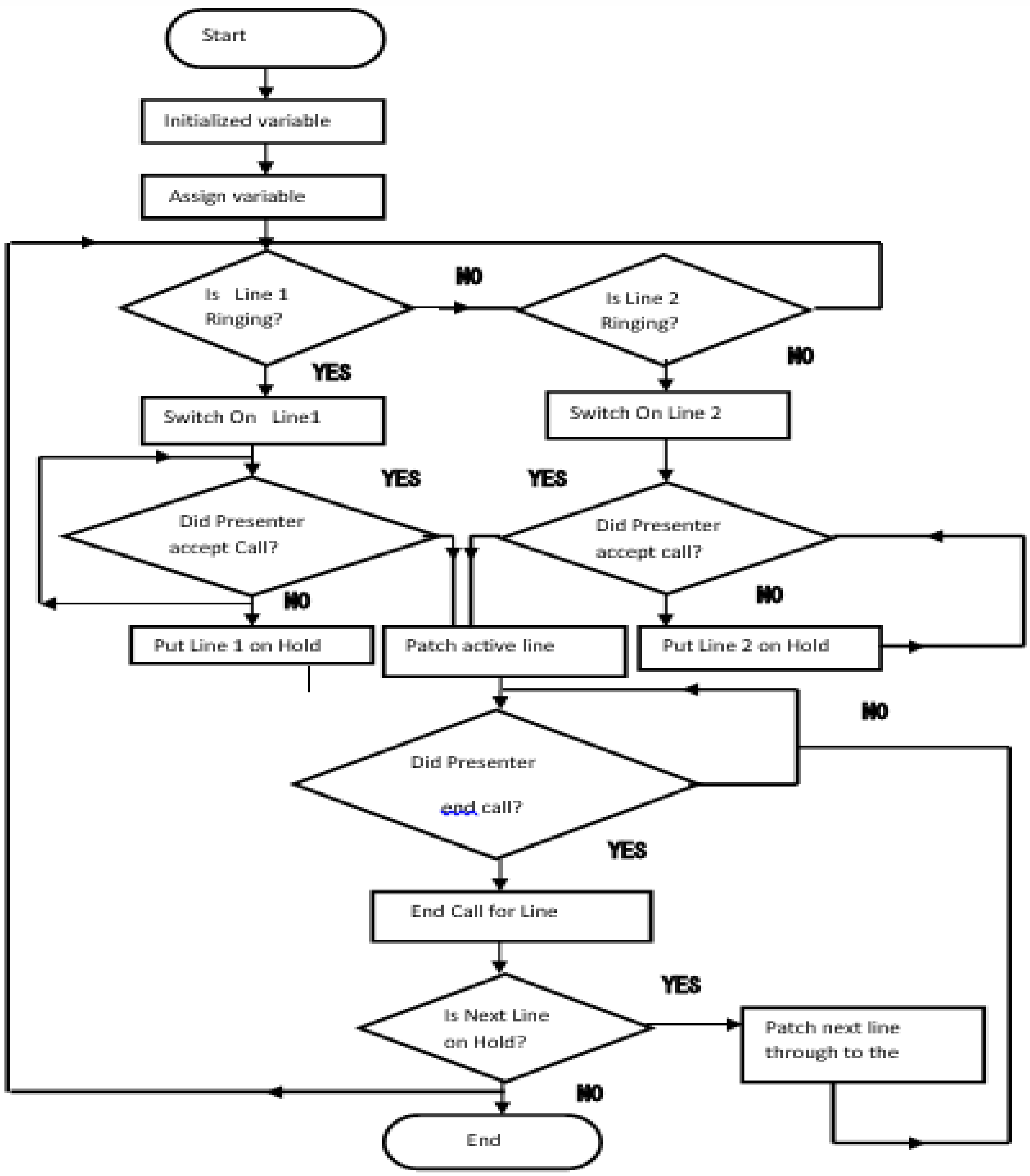

Figure 5: Flowchart of the System

Table 3: Voltage\Current consumption by the Intercom Unit

Experiment no.	Input current	Input voltage
1	54.51mA	15.56V
2	54.62mA	15.57V
3	54.60mA	15.56V
Average	54.61mA	15.56V

Measurements with Active Calls from Contributors:
With an incoming call from the contributors, any of the two lines can become active. Line 1 will continue to be active on ring tone until the presenter accepts the call by switching the blue button of the intercom unit of Figure 7.

Figure7 shows the main control unit indicating line 1 is active

3.2 RELIABILITY EVALUATION OF DEVICE

This method was adopted to assess the reliability of the microcontroller based digital telephone traffic control. It established the stress failure rates of the components used in the design of the device. The processwas based on listing the components of the device, attaining the failure rate of each component from the standard tables of failure rates. The weighing for environment, operating stress, and temperature were the determinant factor. With these relations the overall failure rate is estimated.

$$\lambda_{oi} = n_i \lambda_i W_E W_T W_R (\%/10^3\text{hr}) \qquad (10)$$

where:

λ_{oi} *is overallfailurerate.*

n_i is number of the component used.

λ_i *is* failure rate of individual component.

W_E is enviromental weighing factor.

W_R is operating stress weighing factor.

W_T is temperature weighing factor. The reliability is then calculated using the relation;

$$R = e^{-\lambda t} \qquad (11)$$

where, $\lambda = \Sigma\lambda_{oi}$ and t is time of operation of the device.

The Table 4 gives the components used, their number, and their failure rates their weighing factors and the overall failure rate of the device.

The overall failure rate of the device is 1.146 $\%/10^3$hr.Therefore, reliability of the device that operates for one year

(t = 24 x 365 =8760hr) is calculated as follows:

$$R = e^{-(0.0146x10^{-3}\ x\ 8760)}$$
$$= 0.88 or\ 88\%$$

Table 4. Components Information for Failure Rates.

Component	Number used (ni)	Failure rate $\lambda(\%/10^3\text{hr})$	Weighing factors due to Environment W_E	Temperature W_T	Rating W_R	Overall failure Rate $\lambda_o = n_i\lambda_i W_E W_T W_R (\%/10^3\text{hr})$
Integrated circuit (IC)	5	0.02	2.0	1.5	1.5	0.45
Resistors	14	0.01	2.0	1.5	1.5	0.63
Soldered joints	11	0.001	2.0	1.5	2.0	0.066
						$\lambda = \Sigma\lambda_{oi} = 1.146$

IV. RESULTS AND DISCUSSION

The device was tested after its development to ascertain its performance. Different parts of the system were found working perfectly from the prototype made. The reliability of the circuit was also computed as 88%, which showed that the system designed was very reliable to be used in our environment.

V. CONCLUSION

This work was aimed at addressing a typical problem (incoming calls interference) encountered in broadcast media houses, especially in developing countries like Nigeria. This problem solution was the ability of the developed system to handle incoming calls during phone in programs without interference. Prototype digital telephone traffic control system was developed to handle traffic on two lines. Both hardware and software units of this microcontroller (PIC16F84A) based system were tested and found to be working satisfactorily. The system was test-run in the Ahmadu Bello University FM Radio and was found to handle calls from the two lines free of interference and recorded 88% reliability.

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